ESSAYS ON THE EFFECTS OF MONETARY POLICY IN EMERGING MARKETS

by

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Abstract

The effects of monetary policy on financial markets are less understood in emerging markets than in advanced economies. This dissertation analyzes the effects of foreign and domestic monetary policies on asset prices in emerging markets.

The first chapter documents the channels through which U.S. monetary policy impacts the sovereign bond yields of emerging markets. Unlike traditional decompositions of sovereign yields that rely on a default-free assumption, I propose to decompose the yields of 15 emerging markets into average expected future short-term interest rates, a term premium and compensation for credit risk. I find that the response of emerging market yields to U.S. monetary policy surprises identified with intraday data is economically significant, yet delayed over days. U.S. target, forward guidance and asset purchase surprises lead to a reassessment of policy rate expectations and a repricing of interest and credit risks in emerging markets.

In the second chapter, I use a new dataset of intraday changes in asset prices around policy events to estimate the impact of monetary policy on the exchange rate and the yield curve in Mexico. I find that an unanticipated increase in the policy rate appreciates the currency and flattens the yield curve, in line with the evidence for advanced economies. I show that the existing evidence for emerging markets in which the response of the exchange rate to monetary policy is small, nonexistent or inconsistent with standard open economy models is the result of wide event windows when measuring changes in the exchange rate with daily data.

The last chapter studies the effects of monetary policy actions and statements on the exchange rate, the yield curve and portfolio flows in Mexico. I show that bond yields and portfolio flows respond significantly to surprises about the current policy rate and about its future path communicated via statements; both surprises are identified using intraday data around monetary policy announcements. Domestic and foreign investors rebalance their portfolios over time following monetary policy decisions; for domestic investors, the rebalancing depends on their business model. Meanwhile, the exchange rate only reacts to surprises about the current policy rate and the effect is not persistent.

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To Jackie and Alen

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Chapter 1

Term Premia and Credit Risk in Emerging Markets: The Role of U.S. Monetary Policy

This chapter characterizes how U.S. monetary policy spills over to the sovereign bond yields of emerging markets.

1.1 Introduction

U.S. monetary policy has worldwide consequences, yet the channels through which it affects the sovereign bond yields of emerging markets are not well understood. Since sovereign yields are the benchmark to price other domestic assets, the ability of emerging markets to mitigate any undesired impact from U.S. monetary policy relies on understanding those channels. Decomposing the yields and analyzing how the components respond is a sensible approach, but traditional two-part decompositions are not suitable for the yields of emerging markets because they are assumed to be free of credit risk.

The main contribution of this paper is to empirically quantify the transmission channels of U.S. monetary policy to the sovereign yields of emerging markets. To achieve this, the paper first proposes a novel three-part decomposition of the yields that accounts for credit risk, and then asks how U.S. monetary policy transmits to those components.

Investors holding local currency bonds of emerging markets bear two major risks. One is the risk of not receiving the promised payments. Although emerging markets have increasingly borrowed in local currency over the last two decades (IMF-WB, 2020), they remain prone to default (Reinhart and Rogoff, 2011; Jeanneret et al., 2014; Beers et al., 2020).[1] The other is the risk that inflation erodes the real value of bond payments. The compensation for this risk is the standard term premium. Thus, compensation for credit risk addresses the risk of not receiving the promised payments, whereas the term premium compensates investors for bearing interest rate risk.

To account for credit risk, I construct default-free yields in local currency by essentially swapping the U.S. yield curve into a local currency one using cross-currency swaps. Those synthetic yields can be seen as the borrowing rates paid by a hypothetical local currency bond issuer with no credit risk,[2] and so traditional decompositions can be applied to them. I use a standard affine term structure model augmented with survey data to obtain robust decompositions of the synthetic yields.[3] Such yields have been widely used to study deviations from covered interest rate parity (CIP) but, instead of concentrating on the CIP deviations, I focus on the synthetic yields themselves.[4] To the best of my knowledge, this is the first application of affine term structure models to synthetic yields.

This paper decomposes the nominal (or actual) yields of 15 emerging markets from 2000 to 2019 into three parts. The first two components come from the decomposition of synthetic yields, namely an average expected future short rate and a term premium. The third component is the spread between the nominal and the synthetic yields, which captures the compensation for credit risk in the local currency debt of emerging markets

[1]Before 2000, several emerging markets issued bonds at short maturities and in foreign currency. Nowadays, they mostly issue bonds with longer maturities and in local currency. There have been more than 30 default episodes in LC since 1996 (Jeanneret et al., 2014); examples include Barbados (2018), Jamaica (2013, 2010), Nicaragua (2008, 2003), Argentina (2001), Turkey (1999) and Russia (1998).

[2]Under this approach, the U.S. yield curve serves as a default-free benchmark for other countries. Although Augustin et al. (2019) argue that U.S. sovereign default risk is not zero, it is not volatile enough to affect the results for emerging markets.

[3]Guimarães (2014) shows that affine term structure models augmented with survey data provide robust decompositions of the U.S. and U.K. (nominal) yield curves.

[4]Du et al. (2018b) show that persistent and systematic deviations from CIP reflect a higher regulatory burden for financial intermediaries. Du et al. (2018a) argue that CIP deviations reflect a convenience yield in advanced economies, whereas Du and Schreger (2016) show that they capture a local currency credit spread for emerging markets, which is used by Hofmann et al. (2019) to explain the link between currency appreciations and the compression of the sovereign yield spreads of emerging markets.

(Du and Schreger, 2016).[5] This decomposition gives reasonable estimates for the components. Across emerging markets, average expected short rates, the term premium and the credit risk compensation in the 10-year nominal yield represent on average 4.2, 2.2 and 0.9%, respectively. Although credit risk is an important component, the literature on term structures of emerging market yields has not examined it systematically.[6] By explicitly accounting for credit risk, the second component is a genuine term premium. I show that this term premium compensates investors for bearing inflation uncertainty, consistent with the evidence for advanced economies (Wright, 2011) and with inflation in emerging markets being more volatile than in advanced economies (Ha et al., 2019).

The characterization of the transmission channels of U.S. monetary policy needs both the three-part yield decomposition and the identification of unanticipated policy decisions by the Fed. I distinguish between target, forward guidance and asset purchase surprises following the literature (Gürkaynak et al., 2005; Swanson, 2018). These monetary policy surprises are identified using intraday data around Fed's monetary policy announcements. This is by now a well-established strategy to overcome endogeneity concerns because it isolates the surprise component of monetary policy decisions.

Three main findings summarize the transmission channels of U.S. monetary policy surprises to emerging market yields. First, the responses to target, forward guidance and asset purchase surprises are economically significant but sluggish, and amplify over the month following the surprise. This delayed response is consistent with the evidence for the U.S. and other advanced economies, which Brooks et al. (2019) attribute to a portfolio rebalancing channel and slow-moving capital. Moreover, the effects of asset purchase surprises last longer in emerging market yields than in U.S. yields. Portfolio rebalancing involving emerging market bonds following asset purchases is thus slower.

Second, monetary policy surprises spill over to all yield components, so that unan-

[5]Credit risk here is broadly defined including, for example, (selective) default risk, currency convertibility risk, regulation risk, capital controls, and jurisdiction risk, so compensation for any of these risks is considered as compensation for credit risk even if the country does not default per se.

[6]The analysis of sovereign credit risk traditionally focuses on bonds denominated in foreign currency. For instance, Hilscher and Nosbusch (2010) report the relevance of domestic factors to explain sovereign credit risk, while Longstaff et al. (2011) document the importance of global factors. Bostanci and Yilmaz (2020) study the connectedness of the network of sovereign credit default swaps.

ticipated Fed policy decisions give rise to a reassessment of policy rate expectations and a repricing of risks in emerging markets. Investors expect monetary authorities in those countries to eventually follow the Fed's monetary stance rather than counteract it, given that average expected future short rates decline following target, forward guidance and asset purchase easing surprises. In addition, Fed's unconventional monetary policies aimed at reducing the U.S. term premium, namely forward guidance and asset purchases, ultimately also decrease the term premia in emerging markets. Lastly, long-term credit risk compensation increases following target and forward guidance easing surprises. Loose financial conditions abroad trigger a 'reach for yield' behavior among investors (Hausman and Wongswan, 2011) that can incentivize more borrowing in emerging markets by sovereigns in local currency (Bigio et al., 2018) and by corporates in foreign currency[7]. In either case, the price of default risk (not necessarily the risk itself) increases. This effect can be seen as the fiscal implications in emerging markets of Fed's monetary policies, something that has not been discussed so far in the literature.

Third, since the global financial crisis, U.S. monetary policy has spilled over to emerging markets through a yield curve channel. I show that among emerging markets long-term yields are more interconnected than short-term ones, so the global financial cycle is more relevant for the long end of their curves; equivalently, their monetary autonomy is stronger at the front end of their yield curves (Obstfeld, 2015). U.S. unconventional monetary policies aimed at influencing long-term yields thus limit the monetary autonomy of emerging markets along their yield curves. The effects transmit, in particular, through the expected future short rate as argued by Kalemli-Özcan (2019) as well as via the term premium as suggested by Turner (2014) and Kolasa and Wesołowski (2020). Global risks hit emerging markets even when borrowing in local currency (Carstens and Shin, 2019).

A growing literature analyzes the spillover effects of U.S. monetary policy to the local currency sovereign bond yields of emerging markets. Hausman and Wongswan (2011) report significant spillovers, while Bowman et al. (2015) compare the effects of conventional and unconventional monetary policies. The present paper is nonetheless

[7] Du and Schreger (2017) show that higher reliance on foreign currency borrowing by corporates increases sovereign default risk in emerging markets.

more closely related to the work of Curcuru et al. (2018), Adrian et al. (2019) and Albagli et al. (2019), who decompose the yields to analyze the transmission channels of such spillovers, but it differs in a number of dimensions. Most importantly, this paper explicitly accounts for the credit risk embedded in emerging market yields, and analyzes the effects of different types of monetary policy surprises identified with intraday data.[8]

The rest of the paper proceeds as follows. Section 1.2 explains how to construct the local currency yield curves. Section 1.3 presents the affine term structure model used to decompose the yields. Section 1.4 assesses the yield decompositions. Section 1.5 analyzes the U.S. monetary policy spillovers to emerging market yields. The last section concludes.

1.2 Local Currency Yield Curves

This section explains how to construct the nominal and synthetic local currency (LC) yield curves of emerging markets, and explains that the spread between the two is a model-free measure of the compensation for credit risk. In the next section, the *synthetic* yield curve will be decomposed into average expected future short-term interest rates and a term premium. The three components of the *nominal* yield curve will then be used to characterize the response of emerging market yields to U.S. monetary policy.

1.2.1 Construction of Synthetic Yield Curves

The main idea to construct the synthetic LC yield curves is to use the U.S. yield curve as the benchmark for all other countries and to swap it into LC by adding a foreign exchange forward premium at each maturity. The forward premium compensates investors for the expected depreciation of the currency. In this paper the exchange rate is expressed in LC per U.S. dollar (USD), so a currency depreciates when the exchange rate increases. This approach assumes frictionless financial markets; in particular, it assumes that (i) unconstrained arbitrageurs have access to U.S. and LC bonds, (ii) the derivatives contracts

[8] Rogers et al. (2014) and Rogers et al. (2018) analyze the spillovers on bond yields using surprises identified with intraday data but they focus on advanced economies. Gilchrist et al. (2019) study the effects for advanced and emerging countries but for debt denominated in foreign currency.

used to construct the forward premium have no counterparty risk, and (iii) U.S. yields are free of default risk.[9] Du and Schreger (2016) show that this is a useful benchmark to quantify credit risk in the LC debt of emerging markets.

The zero-coupon synthetic LC yield for an n-period bond at time t, $\widetilde{y}_{t,n}^{LC}$, is defined as

$$\widetilde{y}_{t,n}^{LC} = y_{t,n}^{US} + \rho_{t,n}. \tag{1.1}$$

in which $y_{t,n}^{US}$ denotes the zero-coupon yield for an n-period U.S. Treasury security at time t, and $\rho_{t,n}$ is the n-period forward premium from USD to LC at time t. The calculation of the forward premium depends on the maturity. For maturities shorter than one year, the forward premium is calculated as the annualized difference between the forward and the spot exchange rates. For maturities equal or larger than one year, the forward premium is calculated using cross-currency swaps because outright forwards are less liquid. Since fixed-for-fixed cross-currency swap rates are rarely observed in the market directly, they are constructed using cross-currency basis swaps and interest rate swaps. The idea is to exchange cash flows in the two currencies, USD and LC. Start by swapping fixed payments in LC into floating-rate cash flows in USD using cross-currency basis swaps (referenced to the Libor—London interbank offered rate—in USD), which are then swapped into fixed-rate cash flows in USD using interest rate swaps. Both types of swaps are liquid, marked to market and collateralized instruments, so the bilateral counterparty risk in cross-currency swaps is small.

Since the construction of synthetic yields relies on the U.S. yield curve and currency derivatives, it does not require information about the nominal yields.[10] By contrast, the nominal zero-coupon yield, $y_{t,n}^{LC}$, is constructed directly from quotes of LC bonds actually traded in the market.

According to the CIP condition, the nominal (direct) and the synthetic (indirect) LC interest rates should be equal. Essentially, CIP implies that an issuer should be able to borrow directly or indirectly (synthetically) in LC at the same yield. Du et al. (2018b)

[9] Augustin et al. (2019) argue that U.S. sovereign default risk is not zero. Nevertheless, it is not volatile enough to affect the results in this paper.

[10] Since there is no forward premium for the USD relative to the USD, $\widetilde{y}_{t,n}^{US} = y_{t,n}^{US}$.

show, however, that there are persistent and systematic deviations from CIP. Indeed, the spread between the nominal and synthetic yields ($y^{LC}_{t,n} - \widetilde{y}^{LC}_{t,n}$) measures CIP deviations in sovereign yields. For advanced economies, Du et al. (2018a) argue that CIP deviations measure the difference in the convenience yield of U.S. Treasuries relative to that of the sovereign bonds of other advanced economies. By contrast, Du and Schreger (2016) point out that CIP deviations have a different interpretation for emerging markets.

The nominal-synthetic spread is a model-free measure of the compensation for credit risk in the LC yields of emerging markets. Whereas the nominal yields of advanced economies are usually considered free of credit risk, the nominal yields of emerging markets include a credit risk compensation given the possibility of default (Du and Schreger, 2016, 2017). Since credit risk in the components of the synthetic yields (equation (1.1)) is small, a synthetic yield can be seen as the borrowing rate paid by a hypothetical issuer in LC with no credit risk.

Du and Schreger (2016) show that the nominal-synthetic spread is highly correlated with the rates of credit default swaps (CDS)—financial derivatives aimed to protect investors against default by a bond issuer. However, the nominal-synthetic spread adequately measures credit risk on LC debt, whereas CDS are suitable for studying the sovereign risk in bonds denominated in foreign currency (see, for example, Longstaff et al., 2011). Indeed, according to the International Swaps and Derivatives Association (ISDA), LC bonds governed under domestic law do not trigger CDS payouts.[11] In addition, a credit event for a CDS contract is not always clearly defined.

1.2.2 Construction of Nominal Yield Curves

The construction of the nominal yield curve, $y^{LC}_{t,n}$, uses the Bloomberg Fair Value (BFV) curves. These curves report coupon-equivalent par yields. I convert them into continuously-compounded yields to obtain implied zero-coupon curves (see Gürkaynak et al., 2007).[12] For Brazil and Israel, Bloomberg does not provide BFV curves but zero-

[11] See the ISDA credit derivatives physical settlement matrix.

[12] As a robustness check, I estimate the nominal yield curves from actual prices for some of the countries in the sample using the Nelson–Siegel model. They closely follow the curves reported by Bloomberg.

coupon yields with coupon-equivalent compounding, known as IYC curves, which I also convert into continuously-compounded yields.[13]

The resulting continuously-compounded zero-coupon curve for each country is what this paper refers to as the nominal yield curve $y_{t,n}^{LC}$.

1.2.3 Yield Curve Data

Nominal and synthetic yield curves are constructed for the 15 emerging markets originally studied by Du and Schreger (2016) and, to compare the results, for the 10 advanced economies considered by Du et al. (2018a).[14] All emerging markets in the sample, except Malaysia, have adopted an inflation targeting regime.[15] Some of them adopted it during the sample period.[16]

The data for nominal and synthetic yields is available daily. The sample starts in January 2000 and ends in January 2019. The starting dates, however, vary by country. All the yields for advanced economies start no later than September 2001. The sample sizes for emerging markets are generally smaller. The nominal yields of 9 and the synthetic yields of 7 emerging markets start before March 2004; both types of yields for the rest of the countries start no later than June 2007. There are thus at least 10 years of data for most of the emerging markets in the sample.[17] In principle, this is a reasonable time period for the estimation of the affine term structure model presented in section 1.3.1, but in practice there may be too few interest rate cycles per country. Surveys of professional forecasters help to address this small sample problem, as discussed in section 1.3.3.

The yields have maturities of 3 and 6 months, and 1 through 10 years, ranging from

[13] For some emerging markets, Bloomberg reports both BFV and IYC curves. BFV curves are preferred for several reasons: their history is longer, IYC curves are not available for advanced economies—the benchmark for some of the results reported later—and, compared to the BFV curves, the short end of the IYC curves seems disconnected from the rest of the curve at some dates for a few countries.

[14] Emerging markets: Brazil, Colombia, Hungary, Indonesia, Israel, Korea, Malaysia, Mexico, Peru, the Philippines, Poland, Russia, South Africa, Thailand, Turkey. Advanced economies: Australia, Canada, Denmark, Germany (based on the euro), Japan, Norway, New Zealand, Sweden, Switzerland, the U.K.

[15] Malaysia, however, has several characteristics that are aligned with an inflation targeting regime.

[16] Hungary in June 2001, the Philippines in January 2002, Indonesia in July 2005, Turkey in January 2006 and Russia in 2014. Hungary and Poland were accepted to join the European Union in April 2003.

[17] For Turkey, the nominal yields with a maturity of up to 10 years start on June 2010, although its synthetic yields start on May 2005. For Russia, data on both types of yields start in 2007 but due to low liquidity at the beginning of the sample, here it starts in July 2009.

a minimum of nine to a maximum of twelve maturities per country.[18] The maximum maturity considered for the analysis is 10 years because bonds and swaps with larger maturities have less history and are less liquid, especially for emerging markets who do not issue longer-term bonds as often as advanced economies.

The construction of LC synthetic yield curves involves data from the U.S. yield curve and the forward premium for different maturities, as explained in section 1.2.1. Data for the U.S. zero-coupon yield curve comes from two sources. For maturities of 1 through 10 years, the yields come from the dataset constructed by Gürkaynak et al. (2007), who only consider Treasury securities with coupons. Since Treasury securities with less than one year to maturity behave differently—partly because they are less actively traded than longer-maturity ones—I follow Duffee (2010) and use the estimates from the Center for Research in Security Prices (CRSP), which are robust at the short end of the curve. Specifically, the 3- and 6-month yields are the annualized 13- and 26-week rates (bid/ask average) in the CRSP Risk-Free Rates series.[19]

The data to compute the forward premium also comes from two sources. For maturities of less than one year, I use data on the spot exchange rate along with 3- and 6-month forwards from Bloomberg for all countries but Korea, the Philippines and Thailand, for which the data comes from Datastream. To construct the cross-currency swap rates, I use data on cross-currency basis swaps and interest rate swaps for each available maturity from 1 through 10 years. The data for the swap curves comes from Bloomberg.[20]

Table 1.1 reports descriptive statistics for different tenors of the nominal and synthetic yield curves for the emerging and advanced economies in the sample. The yield curves exhibit standard properties such as an upward slope. At the same time, the table provides information on how the curves of emerging markets differ from those of advanced economies. For instance, the level and the volatility (measured by the standard devia-

[18] All countries have data for maturities from 3 months to 5 years and for 10 years. All countries except Brazil have data for the 7-year maturity. Data for 6, 8 and 9 years vary per country.

[19] The 3- and 6-month yields implied by the fitted model of Gürkaynak et al. (2007) are highly correlated with CRSP yields (0.9985 and 0.9995) but are on average (16 and 10 basis points) higher since 1983.

[20] A spreadsheet with the tickers used in the construction of the forward premiums and in the estimation of the nominal yield curves is available upon request. The file consolidates and expands (with tenors and tickers) similar files kindly posted online in Wenxin Du and Jesse Schreger's websites.

Table 1.1. Descriptive Statistics of Yield Curves

		3M	6M	1Y	2Y	5Y	10Y
Nominal	Emerging Markets						
	Average	5.1	5.3	5.4	5.7	6.3	6.8
	Std. D.	3.2	3.3	3.2	3.2	3.0	2.9
	Advanced Economies						
	Average	2.0	2.1	2.1	2.3	2.7	3.2
	Std. D.	2.1	2.1	2.1	2.1	2.0	1.8
Synthetic	Emerging Markets						
	Average	5.1	5.2	5.3	5.3	5.8	6.3
	Std. D.	4.3	4.1	4.0	3.7	3.4	3.2
	Advanced Economies						
	Average	1.6	1.7	1.8	2.0	2.5	3.2
	Std. D.	2.1	2.1	2.2	2.1	2.0	2.0

Notes: This table reports the average and the standard deviation using end-of-month data for different tenors of the nominal and synthetic yields of the emerging markets and advanced economies in the sample. All figures are expressed in annualized percentage points.

tion) of their curves are larger than those of advanced economies. Also, the short end of their curves is more volatile than the long end, particularly so for the synthetic curve. Lastly, the spread between the nominal and the synthetic yields suggests that the credit risk compensation is on average positive.

Timing

The parameters of the affine term structure models are estimated using end-of-month data, as explained in section 1.3.3. Since the U.S. yield curve is the benchmark to construct the synthetic yield curves, the end-of-month dates are the last business days of each month according to the U.S. calendar.

Getting the timing right is key to adequately measure the responses of emerging market yields to surprises in Fed's policy decisions. The analysis of monetary policy spillovers in section 1.5.3 uses daily changes in nominal and synthetic yields. Since the closing prices in non-Western Hemisphere countries happen before the Fed's monetary policy announcements, their nominal yields are shifted one day back so that their daily changes adequately capture surprises in the announcements. The credit risk compensation for those countries is calculated using the shifted nominal yields.

1.3 Methodology

This section describes the affine term structure model used to decompose the yield curve of each country in the sample, and discusses the difficulties in estimating the parameters of the model. It then explains how survey data helps in the estimation. Among the many applications of the decomposition, this paper exploits it to analyze the transmission channels of U.S. monetary policy to the yields of emerging markets.

1.3.1 Affine Term Structure Model

Let $P_{t,n}$ be the price at time t of a zero-coupon *risk-free* bond with maturity n. The continuously compounded yield on that bond is then $y_{t,n} = -\ln P_{t,n}/n$. In particular, the one-period continuously compounded risk-free rate is $i_t = y_{t,1} = -\ln P_{t,1}$.

If there is no arbitrage, there exists a strictly positive stochastic discount factor that prices all nominal bonds. Let M_{t+1} be the nominal stochastic discount factor. Accordingly, the bond price today is recursively defined as follows

$$P_{t,n} = \mathrm{E}_t^{\mathbb{P}} \left[M_{t+1} P_{t+1,n-1} \right], \tag{1.2}$$

in which $\mathrm{E}_t^{\mathbb{P}}[\cdot]$ denotes the conditional expectation at time t taken using the actual or physical probability measure, $\mathbb{P}$, that generates the data. The existence of the stochastic discount factor also implies that there exists a theoretical risk-neutral or risk-adjusted pricing measure $\mathbb{Q}$—different from the $\mathbb{P}$ measure—that is defined as follows

$$P_{t,n} = \mathrm{E}_t^{\mathbb{Q}} \left[\exp\left(-i_t\right) P_{t+1,n-1} \right], \tag{1.3}$$

in which $\mathrm{E}_t^{\mathbb{Q}}[\cdot]$ also denotes conditional expectation but taken under the $\mathbb{Q}$ measure.

A discrete-time affine term structure model assumes that the dynamics of a K $\times$ 1 vector of unobserved pricing factors or state variables, X_t, follow a first-order vector autoregression, VAR(1), under the risk-neutral measure $\mathbb{Q}$

$$X_{t+1} = \mu^{\mathbb{Q}} + \Phi^{\mathbb{Q}} X_t + \Sigma \nu_{t+1}^{\mathbb{Q}}, \tag{1.4}$$

in which $\mu^{\mathbb{Q}}$ is a $\mathrm{K} \times 1$ vector and $\Phi^{\mathbb{Q}}$ is a $\mathrm{K} \times \mathrm{K}$ transition matrix, Σ is a $\mathrm{K} \times \mathrm{K}$ lower triangular matrix with positive diagonal elements, and $\nu_{t+1}^{\mathbb{Q}}$ is a $\mathrm{K} \times 1$ independent and identically distributed, normal vector with zero mean and covariance equal to the identity matrix conditional on the pricing factors, that is $\nu_{t+1}^{\mathbb{Q}} | X_t \sim \mathcal{N}_{\mathrm{K}}(0, I)$.

The pricing factors drive the dynamics of the one-period interest rate as follows

$$i_t = \delta_0 + \delta_1' X_t, \tag{1.5}$$

in which δ_0 is a scalar and δ_1 is a $\mathrm{K} \times 1$ vector of parameters.

These assumptions imply that the bond price is an exponentially affine function of the pricing factors

$$P_{t,n} = \exp\left(A_n + B_n X_t\right),$$

such that the corresponding continuously compounded yield of the bond is an affine function of those factors

$$y_{t,n}^{\mathbb{Q}} = A_n^{\mathbb{Q}} + B_n^{\mathbb{Q}} X_t, \tag{1.6}$$

in which $A_n^{\mathbb{Q}} = -\frac{1}{n} A_n$, $B_n^{\mathbb{Q}} = -\frac{1}{n} B_n$, where in turn the scalar $A_n = \mathcal{A}(\delta_0, \delta_1, \mu^{\mathbb{Q}}, \Phi^{\mathbb{Q}}, \Sigma, n)$ and the $1 \times \mathrm{K}$ vector $B_n = \mathcal{B}(\delta_1, \Phi^{\mathbb{Q}}, n)$ are loadings that satisfy the recursive equations

$$A_{n+1} = -\delta_0 + A_n + B_n' \mu^{\mathbb{Q}} + \frac{1}{2} B_n' \Sigma \Sigma' B_n, \quad A_0 = 0, \tag{1.7}$$

$$B_{n+1} = -\delta_1 + \Phi^{\mathbb{Q}\prime} B_n, \quad B_0 = 0. \tag{1.8}$$

The yields $y_{t,n}^{\mathbb{Q}}$ are the model's fitted yields, which means that the risk-neutral measure $\mathbb{Q}$ is sufficient for pricing bonds. However, to be able to decompose the yields into an average expected future short-term interest rate and a term premium, the model needs to specify the dynamics for the market prices of risk, which control the transformation between the $\mathbb{Q}$ and $\mathbb{P}$ measures. In this sense, the stochastic discount factor is assumed to be conditionally lognormal

$$M_{t+1} = \exp\left(-i_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\nu_{t+1}^{\mathbb{P}}\right), \tag{1.9}$$

in which λ_t is a $\mathrm{K} \times 1$ vector of market prices of risk. And, following Duffee (2002), it is also assumed to be an affine function of the pricing factors

$$\lambda_t = \lambda_0 + \lambda_1 X_t, \tag{1.10}$$

in which λ_0 is a $\mathrm{K} \times 1$ vector and λ_1 is a $\mathrm{K} \times \mathrm{K}$ matrix of parameters.

A well-known implication of this structure for the market prices of risk is that the dynamics of the pricing factors under the physical measure $\mathbb{P}$ can also be described by a VAR(1) as follows[21]

$$X_{t+1} = \mu^{\mathbb{P}} + \Phi^{\mathbb{P}} X_t + \Sigma\nu_{t+1}^{\mathbb{P}}, \tag{1.11}$$

in which $\mu^{\mathbb{Q}} = \mu^{\mathbb{P}} - \Sigma\lambda_0$, $\Phi^{\mathbb{Q}} = \Phi^{\mathbb{P}} - \Sigma\lambda_1$, $\nu_{t+1}^{\mathbb{P}}|X_t \sim \mathcal{N}_{\mathrm{K}}(0, I)$. Note that the covariance matrix of the shocks is the same under both measures; that is, it is measure independent.

The yields consistent with the expectations hypothesis of the yield curve—as if investors were actually risk-neutral ($\lambda_0 = 0,\ \lambda_1 = 0$)—are obtained as

$$y_{t,n}^{\mathbb{P}} = A_n^{\mathbb{P}} + B_n^{\mathbb{P}} X_t,$$

in which $A_n^{\mathbb{P}} = -\frac{1}{n}A_n$, $B_n^{\mathbb{P}} = -\frac{1}{n}B_n$, and the loadings $A_n = \mathcal{A}(\delta_0, \delta_1, \mu^{\mathbb{P}}, \Phi^{\mathbb{P}}, \Sigma, n)$ and $B_n = \mathcal{B}(\delta_1, \Phi^{\mathbb{P}}, n)$ satisfy the same recursions as those above but using the parameters of the law of motion of the pricing factors under the $\mathbb{P}$ rather than the $\mathbb{Q}$ measure.[22]

The term premium for maturity n at time t, $\tau_{t,n}$, is then estimated as the difference between the yields obtained under the $\mathbb{Q}$ and $\mathbb{P}$ measures[23]

$$\tau_{t,n} = y_{t,n}^{\mathbb{Q}} - y_{t,n}^{\mathbb{P}}. \tag{1.12}$$

[21]The stochastic discount factor in equation (1.9) and the law of motion of the vector of pricing factors in equation (1.11) can be formalized separately or jointly. For instance, in a utility maximization framework, the stochastic discount factor is usually interpreted as the intertemporal marginal rate of substitution.

[22]The loadings are obtained recursively after combining the no-arbitrage condition and the functional form for bond prices. See the appendices in Lloyd (2020) for derivations under both measures.

[23]Note that the term premium is also an affine function of the pricing factors since $\tau_{t,n}$ can be written as $(A_n^{\mathbb{Q}} - A_n^{\mathbb{P}}) + (B_n^{\mathbb{Q}} - B_n^{\mathbb{P}})X_t$.

A key assumption behind this model is that the yield $y_{t,n}$ is free of credit risk, a reasonable assumption for advanced but not for emerging countries for which investors require to be compensated for credit risk (Du and Schreger, 2016, 2017). Thus, while the nominal yield curve $y_{t,n}^{LC}$ is adequate for advanced economies, the synthetic yield curve $\widetilde{y}_{t,n}^{LC}$ better aligns with the risk-free assumption in the case of emerging markets.

Finally, to ensure that the decomposition of nominal yields adds up, the credit risk compensation is computed as

$$\phi_{t,n} = y_{t,n}^{LC} - y_{t,n}^{\mathbb{Q}}. \tag{1.13}$$

Notice that the credit risk compensation equals the spread between the nominal and the fitted ($y_{t,n}^{\mathbb{Q}}$), rather than the synthetic ($\widetilde{y}_{t,n}^{LC}$), yields. However, since the model fits the synthetic yields reasonably well, the credit risk compensation here is largely similar to the LC credit spread reported by Du and Schreger (2016).

Although the unconditional mean of the credit risk compensation in the data is positive, there have been episodes in which it turns negative. These situations are unrealistic and can reflect financial market frictions (Du and Schreger, 2016), including market segmentation and short selling constraints. Thus, the nominal-synthetic spread is a valid measure of credit risk that is far from perfect, but definitely better than ignoring it. Otherwise, estimates of the term premium would be contaminated with credit risk. Given the unrealistic nature of being negative, for the analysis the credit risk compensation is set to zero when it turns negative in the data. In general, those episodes are brief and rare, so the conclusions from the analysis remain the same as if it is allowed to be negative.

Weak Identification

The estimation of the parameters in the affine term structure model only requires zero-coupon yields as an input. While this data provides sufficient information to identify the pricing coefficients under the $\mathbb{Q}$ measure, $\{\mu^{\mathbb{Q}}, \Phi^{\mathbb{Q}}\}$, it is not enough to accurately identify the parameters under the $\mathbb{P}$ measure, $\{\mu^{\mathbb{P}}, \Phi^{\mathbb{P}}\}$. This information imbalance is relevant for the estimation of the term premium (see equation (1.12)). Indeed, poorly identified parameters under the $\mathbb{P}$ measure result in unstable yield decompositions. Different solutions have been proposed in the literature to address this instability.[24]

Survey data provides additional information on the $\mathbb{P}$ dynamics. Guimarães (2014) argues that surveys anchor the long-run mean of interest rates and shows that incorporating survey data on interest rate forecasts in the estimation provides robust decompositions of the U.S. and U.K. yield curves.[25] Since bond yields are highly persistent, the additional information from surveys is particularly relevant when sample sizes are small, in which case there might be too few interest rate cycles in the data. This is precisely the case with emerging markets, so including survey data in the estimation of the term structure model is especially important to obtain robust decompositions of their yields. On top of that, surveys allow for model-free estimates of the term premium, which serve as a robustness check for the model-implied term premium.

1.3.2 Survey Data

Long-term forecasts are particularly helpful to pin down the parameters of the model under the $\mathbb{P}$ measure, $\{\mu^{\mathbb{P}}, \Phi^{\mathbb{P}}\}$. Twice a year Consensus Economics provides 5-year ahead and long-term (between 6 and 10 years ahead) forecasts for consumer inflation and real GDP growth for most of the emerging countries in the sample; the data is available from March 2001 to October 2017.[26] Figure 1.1 plots the inflation forecasts. With the exception of Brazil and Turkey, inflation expectations in emerging markets have been stable or even declining, and are generally within the upper and lower bounds for their inflation target.

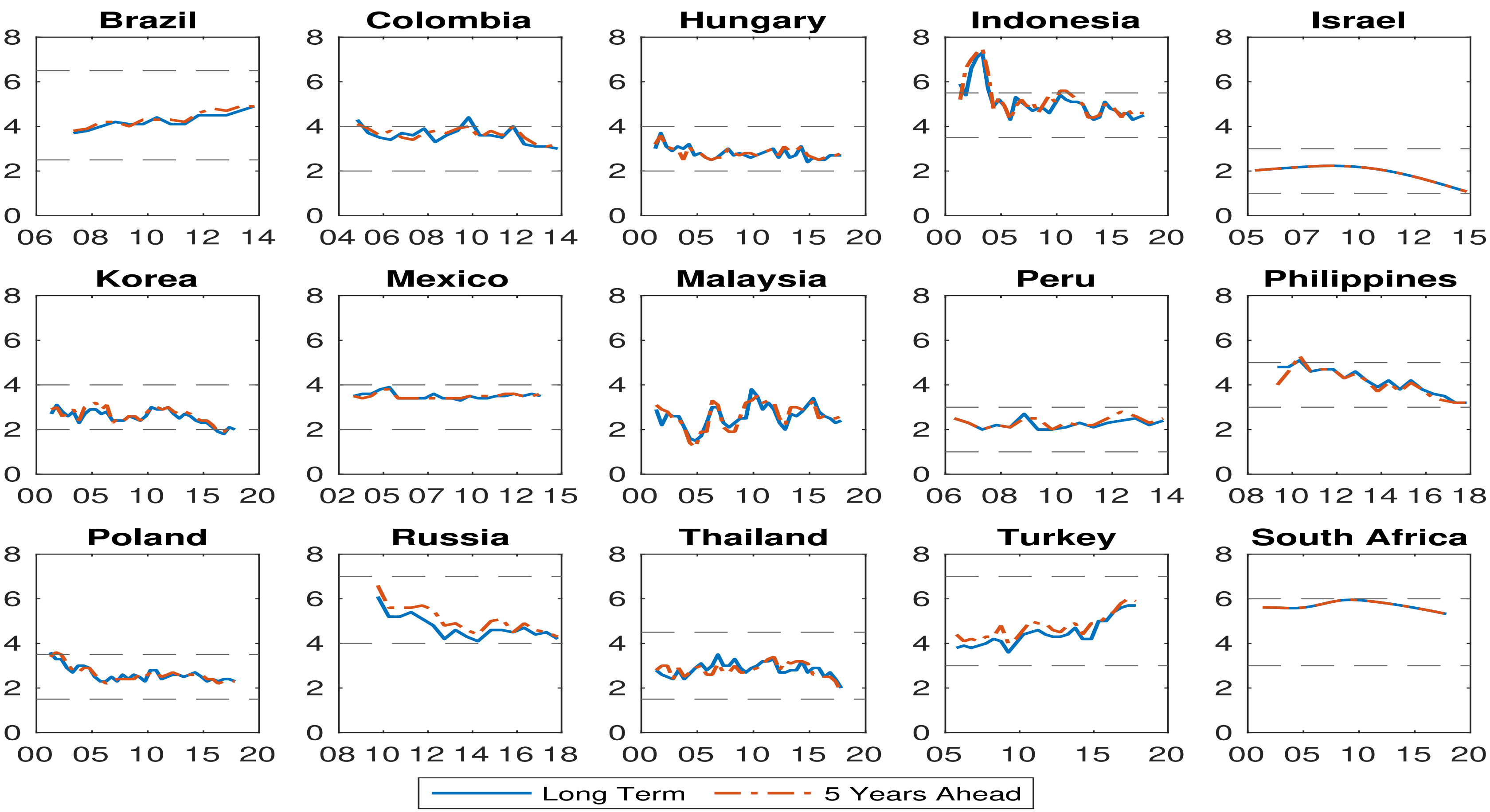
Although there is no source for long-term forecasts for the short rate of emerging markets, they can be inferred from existing data by considering those countries as small open economies and using the Fisher equation. Specifically, the implied forecast for the

[24] Solutions include restrictions on parameters (Duffee, 2010), bias-corrected estimators (Bauer et al., 2012) and complementing bond yield data with survey forecasts of future interest rates (Kim and Wright, 2005; Kim and Orphanides, 2012).

[25] He finds that the term premium estimated with the aid of surveys remains essentially the same after varying the number of pricing factors (from 3 to 5) and the sample periods, even with a sample starting in 1972, which includes the U.S. Great Inflation period.

[26] Data availability varies by country; for example, data for the Philippines starts in 2009, whereas it ends in October 2013 for Latin American countries. Although there is no survey data on long-term inflation forecasts for Israel and South Africa, appendix 1.A shows that trend inflation is a good proxy.

Figure 1.1. Long-Horizon Forecasts of Inflation



Notes: This figure plots the 5-years ahead (dashed line) and the 5- to 10-years ahead or long-term (solid line) average consumer price inflation forecasts against the survey date. For Israel and South Africa, the figure shows the inflation trend, see appendix 1.A. The figure also includes the upper and lower bounds for the domestic inflation target, where applicable. The upper and lower bounds are the most recent ones for each country. For Russia, since it has updated its target range almost every year since early 2000s, the plotted band shows the highest and lowest bounds since 2009.

nominal short rate ($i^{survey}_{t,n}$) equals an expected real interest rate over the same horizon ($r^*_{t,n}$) plus the expected average inflation reported by Consensus Economics ($\pi^{CEsurvey}_{t,n}$). The first term is in turn equal to the expected global real interest rate in USD plus a real foreign exchange forward premium, akin to equation (1.1) but in real terms. The U.S. real interest rate serves as a proxy for the global real interest rate and is inferred by a combination of survey forecasts of future short-term U.S. Treasury bill yields ($i^{SPFsurvey}_{t,n}$) and future U.S. inflation ($\pi^{SPFsurvey}_{t,n}$). Finally, the real forward premium is the residual of regressing the forward premium computed as explained in section 1.2.1 on the expected average inflation from Consensus Economics. Thus, the implied forecast for the nominal short rate is obtained as follows

$$i^{survey}_{t,n} = r^*_{t,n} + \pi^e_{t,n} = \left(i^{SPFsurvey}_{t,n} - \pi^{SPFsurvey}_{t,n}\right) + \rho^{\perp}_{t,n} + \pi^{CEsurvey}_{t,n}. \tag{1.14}$$

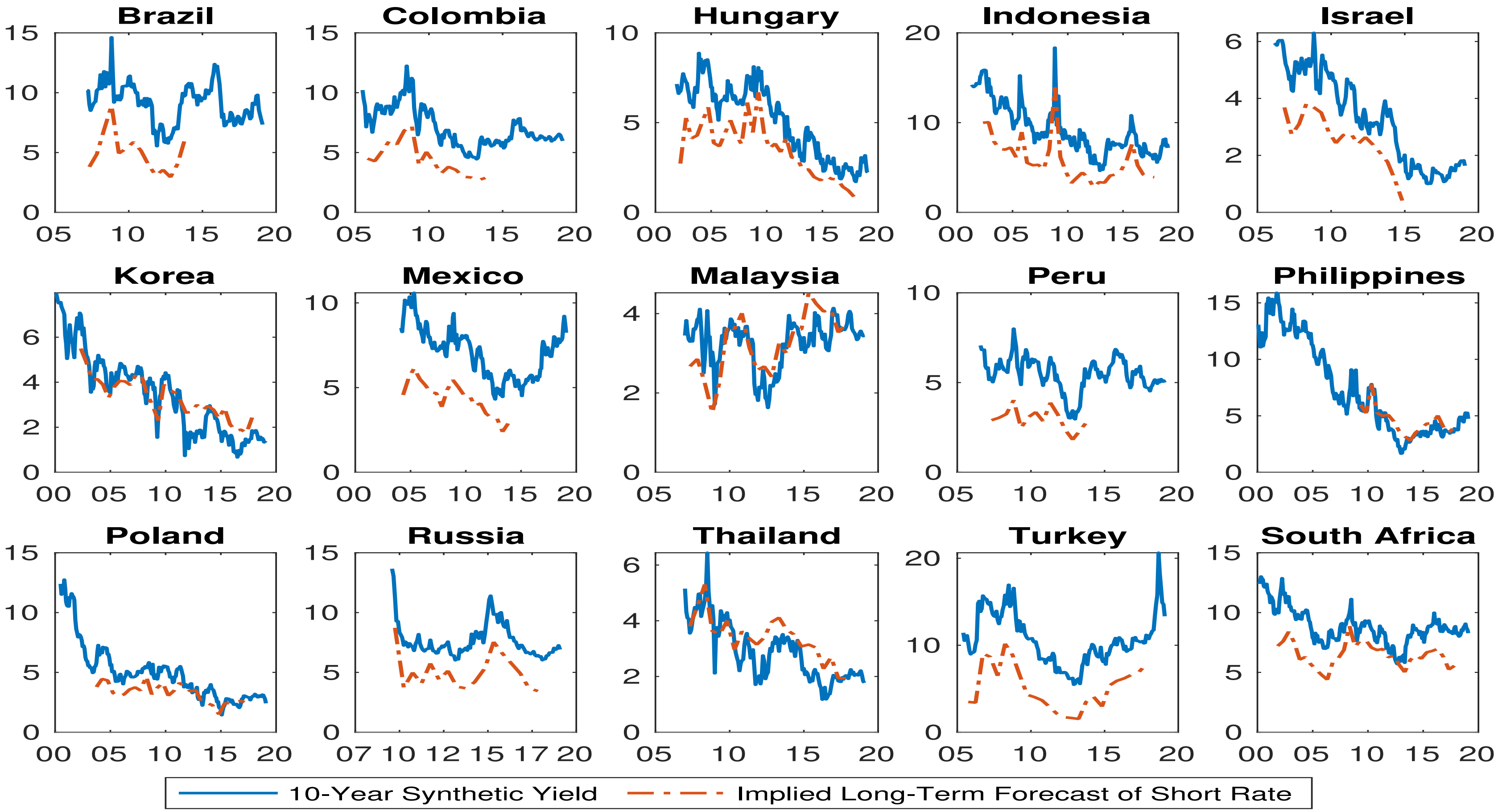
The required U.S. data is available quarterly from the Survey of Professional Forecasters. I use the 5- and 10-year CPI inflation forecasts and, for the T-bill rate, the 10-year forecast and the second longest available one[27]—since there is no 5-year forecast for the T-bill rate—to calculate the implied forecast for the domestic short rate To assess the implied forecasts for the U.S. real rate obtained from surveys, they are compared against the 5- and 10-year zero-coupon real yields constructed by Gürkaynak et al. (2010) who use data from the U.S. TIPS market. The levels of the two series are comparable. TIPS yields are not the benchmark, however, because they are more volatile (their term premium is time varying) and suffer from liquidity problems.

Figure 1.2 shows that the implied long-term forecasts for the short rates are sensible, their level is in line with the synthetic 10-year yield in each country. An alternative way to infer the embedded expectations is to use Taylor rule-type regressions for the policy rate.[28] Both approaches yield similar values for the implied forecasts of the short rates.

[27]The specific series are CPI5YR, CPI10, BILL10 and TBILLD. The BILL10 series is only released in the first-quarter of a year, so I use linear interpolation for the second to fourth quarters. Consensus Economics forecasts are considered at the end of the month in which they are published, at that time the most recent value for the U.S. real interest rate forecast is used in equation (1.14).

[28]I regress the policy rate on its lag, the year-on-year consumer price inflation and the year-on-year real GDP growth for all the countries except Israel and South Africa. The coefficient for the lag of the policy rate is a smoothing parameter that improves the fit of the model to the data. I assume that the estimated parameters for inflation and real GDP growth apply at each of the survey maturities. A potential drawback of this approach is precisely that it requires one to know the expectation of the

Figure 1.2. 10-Year Synthetic Yields and Long-Horizon Implied Forecasts of the Short Rate



Notes: This figure plots the long-horizon implied forecast of the domestic nominal short-term interest rate (dashed line) and the 10-year synthetic yield (solid line). The implied forecast of the short rate is equal to the forecast of the U.S. real short-term interest rate corrected for a real forward premium plus the domestic consumer price inflation forecast, see text for details. The forecast of the U.S. real short-term rate is equal to the difference between the forecast of the three-month U.S. Treasury bill rate and the forecast of the U.S. consumer price inflation.

I assume that the 5-year ahead (implied) forecast for the short rate of each emerging market guides the expected average short rate under $\mathbb{P}$ given by

$$y^e_{t,n} = \frac{1}{n}\mathrm{E}^{\mathbb{P}}_t\left[\sum_{j=0}^{n-1} i_{t+j}\right] = A^e_n + B^e_n X_t,$$

in which $A^e_n = -\frac{1}{n}A_n$, $B^e_n = -\frac{1}{n}B_n$, where in turn $A_n = \mathcal{A}(\delta_0, \delta_1, \mu^{\mathbb{P}}, \Phi^{\mathbb{P}}, 0, n)$ and $B_n = \mathcal{B}(\delta_1, \Phi^{\mathbb{P}}, n)$; that is, A^e_n and B^e_n also satisfy the recursions under the $\mathbb{P}$ measure but with $\Sigma = 0$ (see appendix C of Guimarães (2014)).[29]

Long-term (implied) forecasts are in turn aligned with the 5-year forward rate starting 5 years hence. In the model, the forward rate from n to m periods hence given by $f_{t,n|m} = (my_{t,m} - ny_{t,n}) \,/\, (m-n)$ becomes

$$f^e_{t,n|m} = \frac{1}{m-n}\mathrm{E}^{\mathbb{P}}_t\left[\sum_{j=n}^{m-1} i_{t+j}\right] = A^e_{n|m} + B^e_{n|m} X_t,$$

in which $A^e_{n|m} = (mA^e_m - nA^e_n) \,/\, (m-n)$ and $B^e_{n|m} = (mB^e_m - nB^e_n) \,/\, (m-n)$.

1.3.3 Estimation

The convergence to the global optimum in affine term structure models estimated by maximum likelihood has been traditionally subject to computational challenges and multiple local optima. Joslin et al. (2011) propose a normalization of the affine model that improves the convergence to the global optimum of the likelihood function.

The Joslin et al. (2011) normalization allows for the near separation of the model's likelihood function into the product of the $\mathbb{P}$ and $\mathbb{Q}$ likelihood functions, and reduces the dimension of the parameter space from $(\delta_0, \delta_1, \mu^{\mathbb{Q}}, \Phi^{\mathbb{Q}}, \Sigma)$ to $(i^{\mathbb{Q}}_\infty, \lambda^{\mathbb{Q}}, \Sigma)$, where $i^{\mathbb{Q}}_\infty$ is the short rate under $\mathbb{Q}$ in the long-run and $\lambda^{\mathbb{Q}}$ is a K $\times$ 1 vector of ordered eigenvalues of $\Phi^{\mathbb{Q}}$. It is common to assume that K linear combinations of the N observed bond yields are measured without error, K $<$ N, so that N $-$ K linear combinations of yields

policy rate for the previous forecast horizon. Nevertheless, it is reasonable to assume stationarity for the long-term forecasts (5 and 10 years), in which case only survey data for inflation and GDP growth are needed after dividing their coefficients by 1 minus the coefficient for the lag of the policy rate (due to stationarity). Data for the dependent variable comes from the policy rate statistics of the Bank for International Settlements.

[29] The difference between $y^{\mathbb{P}}_{t,n}$ and $y^e_{t,n}$ is a convexity term due to Jensen's inequality, which increases with maturity. In practice, however, this term usually becomes relevant for maturities beyond ten years. Further, the term is constant across maturities in homoskedastic models like the ones used in this paper.

are measured with error. Following Joslin et al. (2011), I consider that the first three principal components—usually referred to as the level, slope and curvature—of the yield curve in each country are the linear combinations of yields measured without error.[30]

The estimation of the affine model uses the Joslin et al. (2011) normalization and follows a two-step procedure. First, the $\mathbb{P}$ parameters are estimated by OLS of the VAR in equation (1.11) using the K principal components as pricing factors. This step provides initial values for the maximum likelihood estimation of the matrix Σ. Then, taking $\widehat{\mu}^{\mathbb{P}}$ and $\widehat{\Phi}^{\mathbb{P}}$ as given, the $\mathbb{Q}$ parameters are estimated by maximum likelihood.

The estimation uses end-of-month data on *risk-free* yield curves; that is, synthetic yields ($\widetilde{y}^{LC}_{t,n}$) for emerging markets and nominal yields ($y^{LC}_{t,n}$) for advanced economies. Only yield data is available for advanced economies, whereas for emerging markets the model is augmented with survey data on the last day of the month for which the surveys were published.[31] Since survey data is available twice a year (whereas yield data for the estimation is monthly), it is regarded as missing in non-release dates.

Survey-Augmented Model

The Kalman filter is well-suited to handle missing data. The transition equation is the law of motion of the pricing factors under the $\mathbb{P}$ measure given in equation (1.11). The dimension of the observation equation varies depending on the availability of survey data.

On months in which there is no data on survey expectations, the observation equation adds measurement error to the fitted yields in equation (1.6) for each of the N maturities

$$\mathbf{y}_t = \mathbf{A} + \mathbf{B}X_t + \mathbf{\Sigma}_Y \mathbf{u}_t, \tag{1.15}$$

in which $\mathbf{y}_t$ is an $\mathrm{N} \times 1$ vector of observed bond yields, $\mathbf{A}$ is an $\mathrm{N} \times 1$ vector with elements

[30] On average, the first three principal components explain more than 99.5% of the variation in the synthetic yields of emerging markets and 99.9% in the nominal yields of advanced economies.

[31] From 2001 to 2014, data is available in March and September for countries covered in the Eastern European release; starting in October 2014, it is released on April and October. For the rest of emerging markets, forecasts have always been released on April and October. I do not have access to survey data for advanced economies. They are, however, not the main focus of this paper, the affine model is estimated for them just for comparison purposes. Moreover, the results reported later for them are more comparable with other studies that do not use survey data. Finally, there are less concerns about small sample sizes for advanced economies.

$A_n^{\mathbb{Q}}$, $\mathbf{B}$ is an N $\times$ K matrix with rows equal to $B_n^{\mathbb{Q}}$ for $n = 1, \ldots, \mathrm{N}$, $\mathbf{u}_t \sim \mathcal{N}_{\mathrm{N}}(0, I)$ and $\mathbf{\Sigma}_Y$ is a lower triangular N $\times$ N matrix with positive elements on the diagonal.

On months when survey data is available, the observation equation increases by the number of survey forecasts S as follows

$$\begin{bmatrix} \mathbf{y}_t \\ \mathbf{y}_t^S \end{bmatrix} = \begin{bmatrix} \mathbf{A} \\ \mathbf{A}^S \end{bmatrix} + \begin{bmatrix} \mathbf{B} \\ \mathbf{B}^S \end{bmatrix} X_t + \begin{bmatrix} \mathbf{\Sigma}_Y \mathbf{u}_t & \mathbf{0} \\ \mathbf{0} & \mathbf{\Sigma}_S \mathbf{u}_t^S \end{bmatrix}, \tag{1.16}$$

in which $\mathbf{y}_t^S$ is an S $\times$ 1 vector of survey forecasts with elements $i_{t,n}^{survey}$, $\mathbf{A}^S$ is an S $\times$ 1 vector with elements A_n^e or $A_{n|m}^e$, $\mathbf{B}^S$ is an S $\times$ K matrix with rows equal to B_n^e or $B_{n|m}^e$ for $n = 1, \ldots, \mathrm{S}$, $\mathbf{u}_t^S \sim \mathcal{N}_{\mathrm{S}}(0, I)$ and $\mathbf{\Sigma}_S$ is a lower triangular S $\times$ S matrix with positive elements on the diagonal.

To estimate the survey-augmented model, I follow Guimarães (2014) and Lloyd (2020) in two aspects. First, I use the estimated parameters from the Joslin et al. (2011) normalization as initial values for the Kalman filter. Second, I assume homoskedasticity in the errors of yields and surveys, so that $\mathbf{\Sigma}_Y = \sigma_y I_{\mathrm{N}}$ and $\mathbf{\Sigma}_S = \sigma_s I_{\mathrm{S}}$, in which I_{N} and I_{S} are N $\times$ N and S $\times$ S identity matrices, reducing the number of parameters to be estimated.

It is important to acknowledge that although surveys contain useful information, have good forecasting properties and help to anchor the model to reality, they are not a panacea. For instance, surveys might not represent market expectations nor the expectations of the marginal investor,[32] they might also be subject to measurement error, and relying too much on them can be counterproductive as it may lead to overfitting. Thus, I consider them as imperfect or 'noisy' measures of expectations. Accordingly, I follow Kim and Orphanides (2012) by fixing σ_s at a conservative level of 75 basis points.

Estimating Daily Pricing Factors

The parameters estimated with monthly data can be used to estimate the pricing factors at the daily frequency (Adrian et al., 2013). The model is not estimated directly at the

[32] Notwithstanding, in the case of the U.S., when comparing the 5-year ahead CPI inflation median forecast from the Survey of Professional Forecasters against the Survey of Primary Dealers and the Survey of Market Participants, the absolute difference over 2015:I and 2020:II is on average 5 and 13 basis points, respectively.

daily frequency because there is noise that can undermine the estimation.

The Kalman filter maximum likelihood setup explained above gives estimates for both the parameters and the pricing factors. I regress the estimated monthly pricing factors on the end-of-month observed yields to obtain the matrix of loadings implied by those pricing factors, and an intercept. The matrix of loadings multiplied by the daily yields, plus the intercept, gives an estimate of the daily pricing factors. Finally, the estimated parameters (with monthly data) along with the estimated daily pricing factors are used to fit—and decompose—the yields at the daily frequency.

1.4 Decomposing the Yields of Emerging Markets

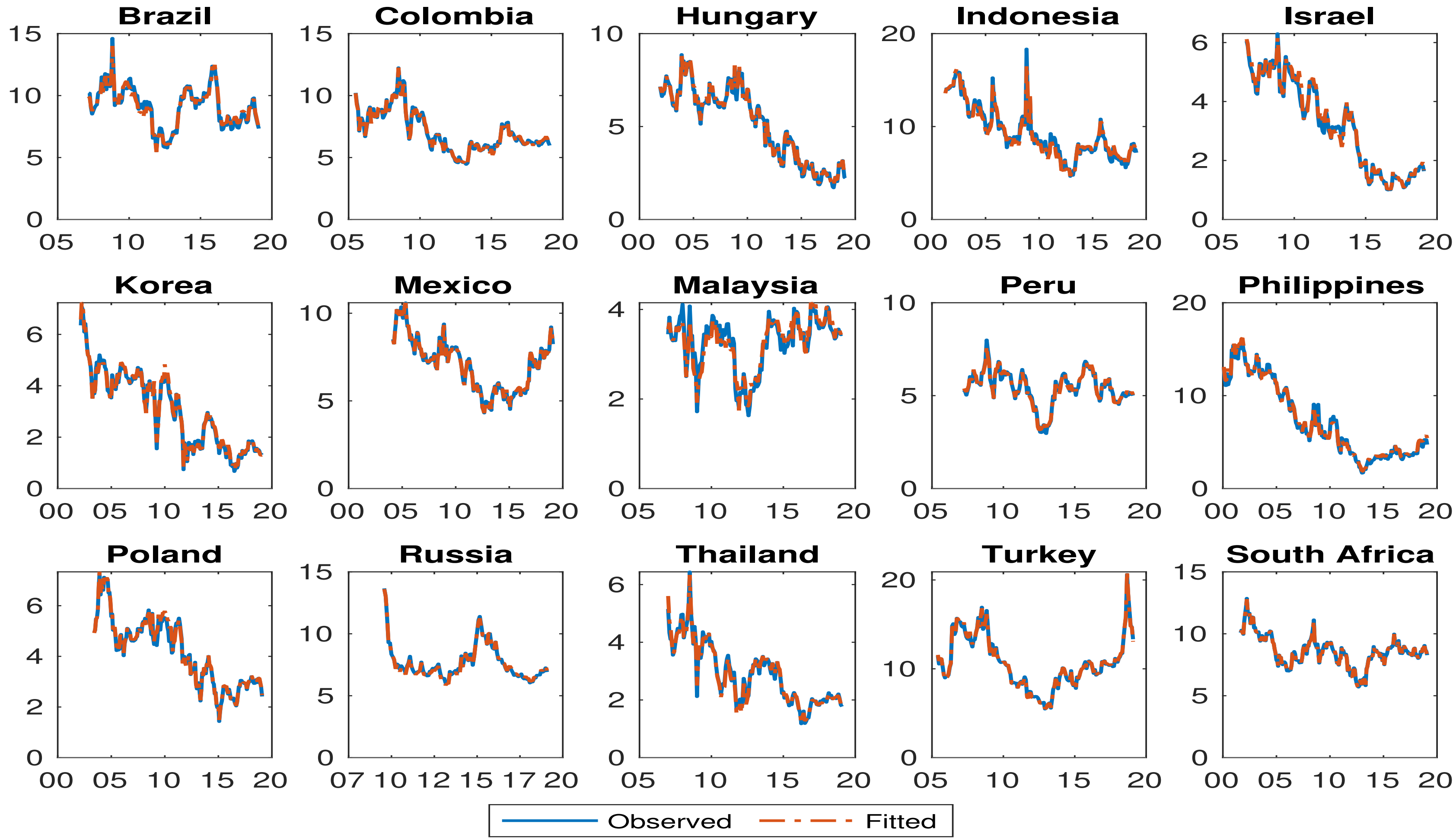
This section shows that the decompositions of the sovereign yields of emerging markets obtained with the survey-augmented model are sensible. It highlights the benefits of using synthetic curves and survey data when analyzing those yields. Among the many potential applications of the decompositions, the next section applies them to characterize the response of emerging market yields to U.S. monetary policy.

1.4.1 Model Fit

Figure 1.3 illustrates the fit of the model for the synthetic yields. The focus is on the 10-year maturity for the sake of brevity. In general, the model fits the data reasonably well. The squared root of the average (across months and maturities) squared difference between the actual and the fitted yields is commonly used to summarize the fitting errors. The average fitting error for the synthetic yields of emerging markets is 16 basis points, a reasonable fit. For reference, the average fitting error for the nominal yields of the advanced economies in the sample is 5 basis points, in line with previous studies (Wright, 2011). The dynamics of emerging market yields are thus relatively harder to capture.[33]

[33]Notwithstanding, it is important to keep in mind that for some countries, large fitting errors might be an indication of less liquid and deep markets.

Figure 1.3. Model Fit: 10-Year Synthetic Yields of Emerging Markets



Notes: This figure plots the fitted (dashed line) and the actual (solid line) 10-year synthetic yields. The fitted yield is obtained after estimating the survey-augmented affine term structure model.

1.4.2 Robustness

The estimated model is used to decompose the yields, but the extent to which any application provides valuable insights hinges on the reliability of the decomposition. To assess its robustness, I compute the standard errors for each component using the delta method. Specifically, since each yield component Ψ is a function of the parameters θ in the model, $\Psi = g(\theta)$, its distribution is calculated based on the following

$$\sqrt{\mathrm{N}}\left(\widehat{\Psi} - \Psi\right) \xrightarrow{d} \mathcal{N}\left(0, \Gamma\,\Omega\,\Gamma'\right),$$

in which Ω is the asymptotic covariance matrix of the estimator $\widehat{\theta}$ and Γ is the Jacobian matrix of partial derivatives calculated numerically. Ω is estimated using the sample Hessian estimator $\widehat{\Omega} = \widehat{\mathcal{H}_\theta}^{-1}$, for which the second derivative matrix of the log-likelihood function evaluated at the optimum, $\widehat{\mathcal{H}_\theta}$, is also calculated numerically.

Although there is uncertainty in both the parameters and the pricing factors after the estimation, the effect of uncertainty associated with the pricing factors on each component is usually small.[34] Therefore, when applying the delta method, I assume that the pricing factors are known with certainty. Figures 1.D.1 and 1.D.2 in the appendix display the term premium and the credit risk compensation along with their confidence bands. The bands seem reasonable and illustrate the benefits of using survey data. Specifically, surveys help in obtaining robust yield decompositions for emerging markets, consistent with the findings of Guimarães (2014) for the U.S. and the U.K.

1.4.3 Decomposition Assessment

Table 1.2 summarizes the decomposition of the nominal yields of emerging markets.[35] Average expected short rates explain most of the variability in nominal yields. Meanwhile, the relevance of the term premium increases with maturity, whereas the credit

[34] To verify this, at each period, I compute the standard errors by pre- and post-multiplying the variance of the pricing factors (generated by the Kalman filter) by the respective factor loadings for the fitted yields, the average expected future short rate and the term premium. In all cases, the average standard error (over time and across countries) is less than 9 basis points for emerging markets, and less than 3 basis points for advanced economies.

[35] The decompositions for advanced economies are not displayed for two reasons. First, they have already been studied before, see for instance Wright (2011) and Adrian et al. (2019). Second, the dataset does not include survey data for advanced economies and so their decompositions may not be robust. They are nonetheless a useful benchmark to assess some results (e.g. average fitting errors above).

Table 1.2. Descriptive Statistics for the Decomposition of Emerging Market Yields

	3M	6M	1Y	2Y	5Y	10Y
	Expected Short Rate					
Average	4.9	4.9	4.9	4.9	4.7	4.2
S. Dev.	3.7	3.4	3.1	2.9	2.5	2.1
	Term Premium					
Average	0.2	0.3	0.3	0.5	1.1	2.2
S. Dev.	1.0	1.3	1.4	1.4	1.6	2.0
	Credit Risk Compensation					
Average	0.7	0.7	0.8	0.8	0.9	0.9
S. Dev.	1.0	0.9	0.9	0.9	0.9	0.9

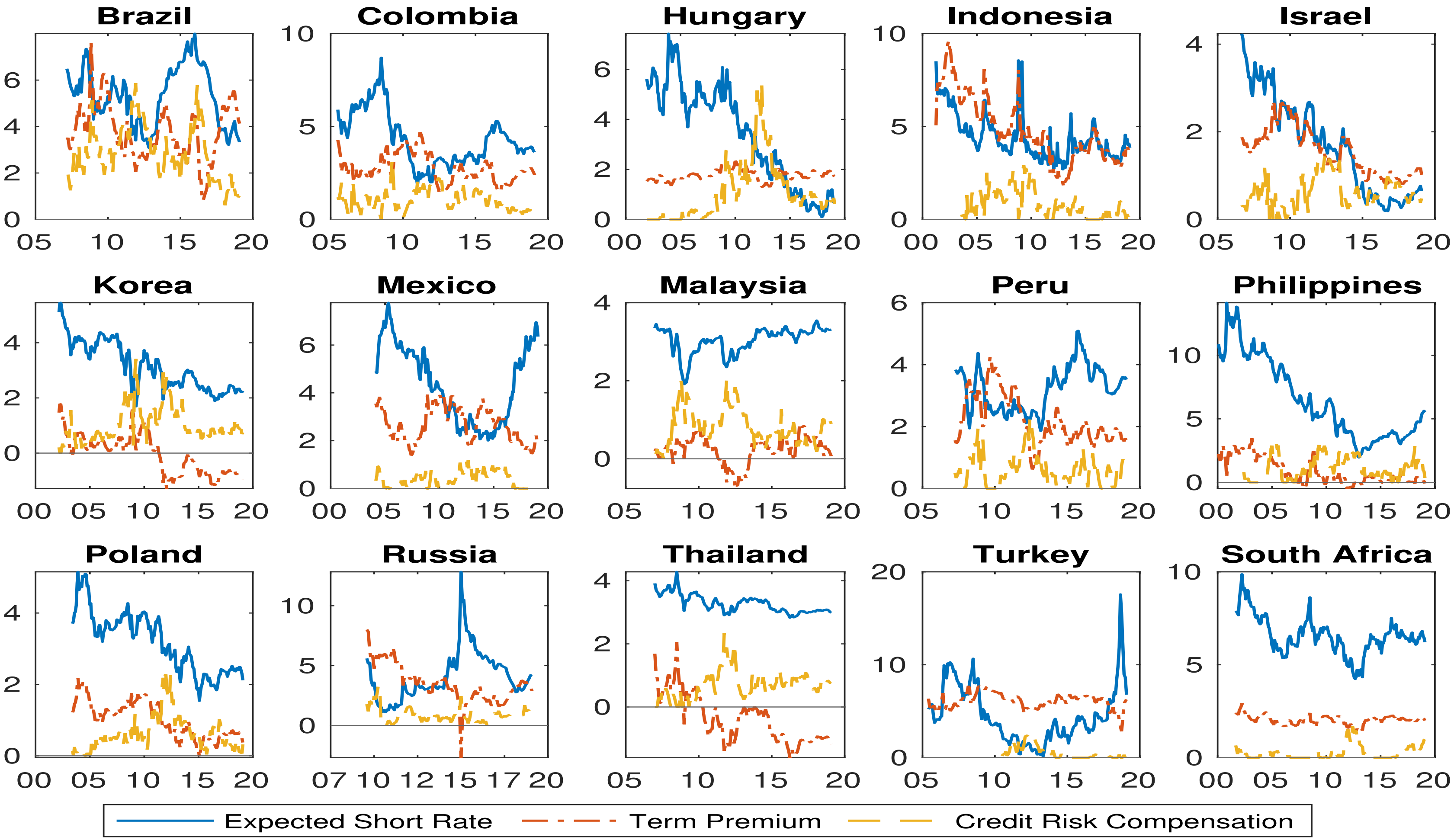
Notes: This table reports the average and the standard deviation using end-of-month data for different tenors of the components of the emerging market nominal yields. All figures are expressed in annualized percentage points.

risk compensation is broadly stable. On average, the three parts respectively represent around 58, 30 and 12% of the 10-year nominal yields of emerging markets.

Figure 1.4 shows the decomposition of the 10-year yield for each country, from which two patterns emerge. First, the term premium and the credit risk compensation are time-varying and both play an important role in the dynamics of yields. Although their relative importance varies by country, the term premium plays a relatively bigger role, in general. Second, there is a downward trend in the expected future short rate and the term premium of several countries, consistent with the evidence for advanced economies (Wright, 2011; Adrian et al., 2019).

In addition, the results for individual countries are consistent with their particular circumstances. For instance, the expected short rate in Mexico increased during the tightening cycle that started following the 2016 U.S. presidential election, after which market participants expected a deterioration in the bilateral relation. The credit risk compensation for Hungary increased after 2010, when the current populist government came into power. Also, the term premium in Poland declined after the global financial crisis as in other European countries in response to the unconventional monetary policies of the European Central Bank. The following sections assess each part individually.

Figure 1.4. Decomposition of the 10-Year Nominal Yields of Emerging Markets



Notes: This figure plots the components of the 10-year nominal yields of emerging markets. The yields are decomposed into an average expected future short-term interest rate (solid line), a term premium (dash-dotted line) and a credit risk compensation (dashed line).

Expected Future Short Rate

Figure 1.5 shows that the 10-year expected future short rate agrees with the (inferred) long-term forecasts for the short rate reasonably well, even though the model does not rely too much on them given the conservative value of 75 basis points used for σ_s. When σ_s is allowed to be estimated, its average value across all emerging markets is 31 basis points. Yet the results are based on the conservative value as discussed in section 1.3.3.

Term Premium

While the (bond) risk premium is usually associated with the term premium in advanced economies, the two concepts are different in emerging markets. The purpose of leveraging on synthetic yields (and surveys) is to estimate a genuine term premium, clean of credit risk. This subsection assesses the sensibility of this 'clean' term premium.

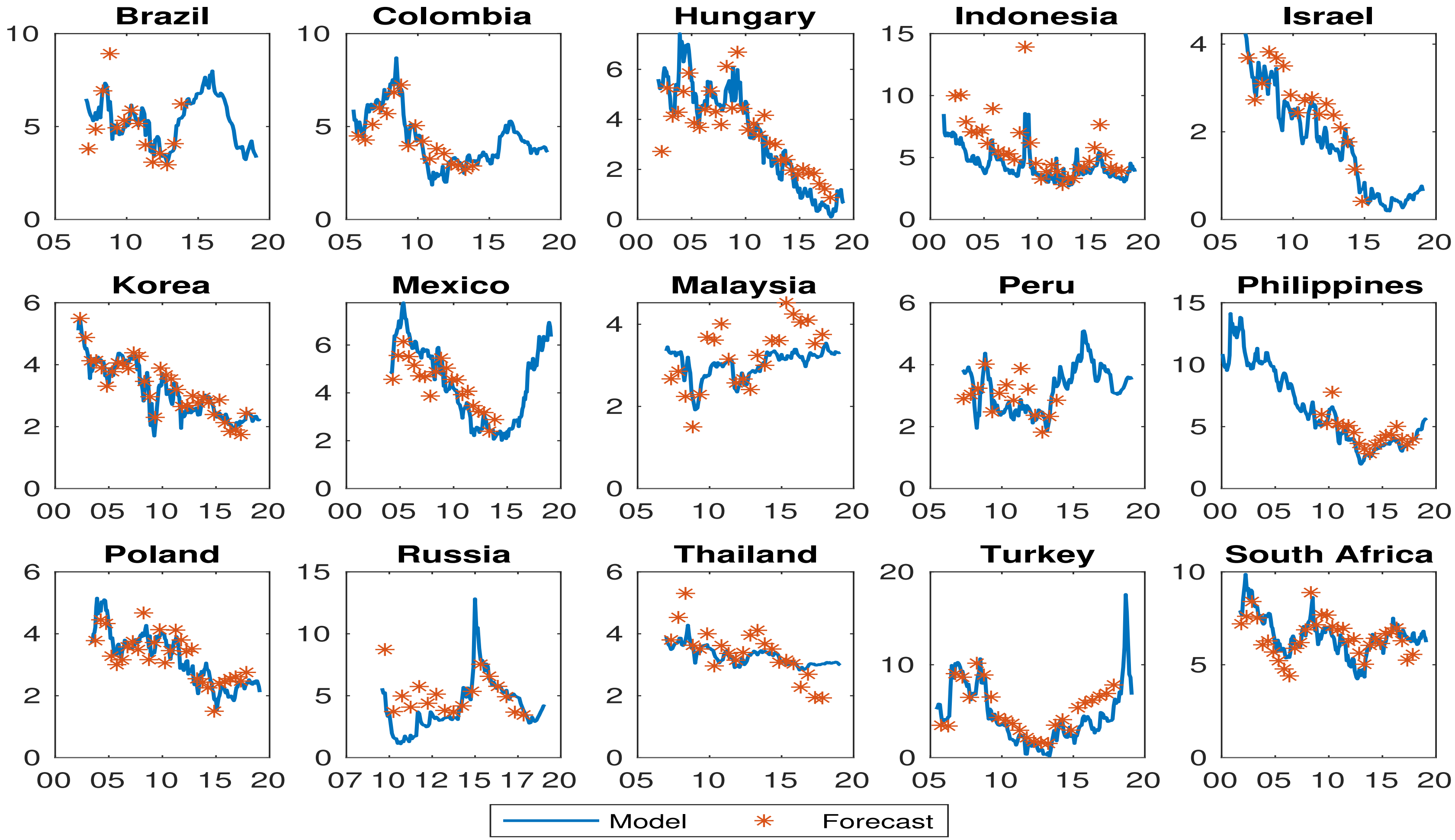
The survey-based term premium serves as a robustness check for the model-implied term premium. It is a model-free measure that equals the difference between the *synthetic* yield and the short rate forecast over the same horizon. Since the model-implied expectations track the short rate forecasts closely (see figure 1.5), the two measures of term premia comove positively, with a correlation of 0.52 across countries.

Wright (2011) documents a downward trend in the term premia of advanced economies and argues that it owes in part to a reduction in inflation uncertainty. Since inflation in emerging markets tends to be higher and more volatile than in advanced economies (Ha et al., 2019), it is reasonable to assume that the relationship between the term premia and inflation uncertainty is particularly relevant in emerging markets. To test this hypothesis, I run the following panel regressions

$$\tau_{i,t} = \alpha_i + \beta_1 \sigma^{\pi}_{i,t} + \beta_2 GDP_{i,t} + u_{i,t}, \tag{1.17}$$

in which α_i are country fixed effects, $\sigma^{\pi}_{i,t}$ is a measure of inflation uncertainty, $GDP_{i,t}$ is the domestic real GDP growth to control for the business cycle, and $u_{i,t}$ is the error term. The dependent variable $\tau_{i,t}$ is the model-implied term premium at different maturities. Following Wright (2011), the measure of inflation uncertainty is the standard

Figure 1.5. Long Horizon Forecasts vs Model-Implied 10-Year Expected Future Short Rate



Notes: This figure plots the long-horizon forecast of the domestic short-term interest rate (asterisk) and the 10-year expected future short-term interest rate implied by the model (solid line).

deviation of the permanent component of inflation based on the Stock–Watson unobserved components stochastic volatility (UCSV) model, estimated using quarterly data for each country.[36] To test for significance, I use the Driscoll–Kraay estimator that allows the errors to be correlated across countries and over time.[37]

Table 1.3 shows that the response of the term premium to the standard deviation of the permanent component is significant and increases with maturity. The result becomes stronger after controlling for the business cycle. Even though the specification might be subject to econometric problems since it involves persistent variables and ignores measurement error, the results are aligned with the view that term premia compensate investors for bearing inflation uncertainty also in emerging markets.

Finally, a term premium becomes negative when investors see bonds as hedges and are therefore willing to give up some investment return. This phenomenon has been reported for advanced economies before, especially after the global financial crisis. Figure 1.D.3 in the appendix shows that negative term premia is not an advanced economy phenomenon. In Asia, the demand for LC bonds has increased since 2011 due to strong macroeconomic fundamentals (IMF-WB, 2020), which partly explains the negative term premia seen for Korea, Malaysia, the Philippines and Thailand. Moreover, figure 1.D.3 in the appendix also shows that some countries experience negative term premia only at the short end of their yield curves, suggesting that investors in LC bonds have a particular preference for short-term LC bonds, especially after the global financial crisis.[38]

Credit Risk Compensation

The role of the credit risk compensation in explaining yield variation is non-negligible (see table 1.2), and thus it matters which curve is used (nominal or synthetic) for decomposing the yields of emerging markets. Unlike the term premium, no clear trend is visible for the credit risk compensation, nor a pattern is detected when looking across maturities.

[36] The UCSV model assumes that inflation has permanent and transitory components subject to uncorrelated shocks that vary over time.

[37] The Pesaran test of cross-sectional independence is rejected in all cases at the 1% significance level.

[38] Notice that in figure 1.D.3 term premia increase with maturity, indicating that long-term bonds are seen as riskier than short-term bonds.

Table 1.3. Term Premia and Inflation Volatility

	6 Months		1 Year		2 Years		5 Years		10 Years	
UCSV-Perm	79.8*	81.1*	78.8**	93.0**	84.4***	105.2***	98.3***	128.7***	118.3***	159.3***
	(30.3)	(34.0)	(23.2)	(32.6)	(20.2)	(27.5)	(18.1)	(25.3)	(18.4)	(27.0)
GDP Growth		-0.49		0.021		1.35		1.66		-0.11
		(2.26)		(2.64)		(1.95)		(1.41)		(2.62)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lags	3	3	3	3	3	3	3	3	3	3
No. Countries	15	14	15	14	15	14	15	14	15	14
Observations	870	796	870	796	870	796	870	796	870	796
R^2	0.07	0.06	0.06	0.06	0.08	0.10	0.13	0.16	0.14	0.18

Notes: This table reports the slope coefficients of panel data regressions of the model-implied term premia for different maturities on the standard deviation of the permanent component of inflation according to the UCSV model (UCSV-Perm) and GDP growth. The sample includes quarterly data for 15 countries starting in 2000:I and ending in 2018:IV. The term premia is expressed in basis points. GDP growth is expressed in percent. Driscoll–Kraay standard errors are in parenthesis; lag length up to which the residuals may be autocorrelated is indicated. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

The dynamics are in line with the results reported by Du and Schreger (2016) who, in particular, show that it is highly correlated with the CDS of the respective country.

Given that both the term premium and the credit risk compensation help explain yield variation in emerging markets, a natural question is whether and how they are related. However, while the term premium compensates investors for bearing the uncertainty that interest rates might suddenly increase, the credit risk compensation actually rewards them for two things. One is a compensation for the *expected* loss owing to default, whereas the other compensates them for bearing the *uncertainty* that defaults might be larger than expected. Attempting to isolate those two parts is beyond the scope of this paper. Therefore, interpreting any potential correlation between the term premium and the credit risk compensation is not straightforward. For several countries, the term premium and the credit risk compensation are negatively correlated in the data as is the case between the average expected future short rates and the credit risk compensation, which suggests that the expected component of the credit risk compensation is empirically more relevant.[39] Intuitively, inflating away the debt would reduce the need to default. Galli (2020) shows that inflation and default are indeed substitutes in models of debt dilution, although he argues for a positive correlation between inflation and default.[40]

1.5 U.S. Monetary Policy Spillovers

This section applies the decomposition described in previous sections to analyze the transmission channels of U.S. monetary policy to emerging market yields. It documents a strong and persistent response of emerging market yields to U.S. monetary policy surprises, and provides evidence of a yield curve channel for the U.S. monetary policy.

[39] One the one hand, the term premium and the *uncertainty* component of the credit risk compensation are likely to move in the same direction. On the other hand, the average expected future short rates and the *expected* component of the credit risk compensation are likely to move in opposite directions.

[40] Alternatively, market segmentation can also explain the negative correlation. For instance, if only certain investors require to be compensated for bearing risks, synthetic yields could increase (potentially due to a higher term premium) but not nominal yields, reducing the spread between the two.

1.5.1 The Yield Curve Channel

Under the traditional Mundell-Fleming trilemma—the impossibility of combining free capital flows, a fixed exchange rate and an independent monetary policy—a flexible exchange rate helps to insulate a financially-open economy from shocks abroad. Rey (2013) argues that a flexible exchange rate does not fully offset those shocks because there is a global financial cycle—mainly driven by U.S. monetary policy—operating through channels other than the exchange rate, like the comovement of global asset prices and cross-border bank lending. The cycle thus drives portfolio flows in or out of emerging markets, influencing their domestic financial conditions.

The literature describes different mechanisms—that can be collectively referred to as the yield curve channel—through which the global financial cycle in general and U.S. monetary policy in particular influence the yields of emerging markets. Central banks in those countries can independently exert control over the short end of their yield curves, but are less powerful swaying the long end because long-term yields are more influenced by global forces than short-term yields (Obstfeld, 2015). Therefore, the global financial cycle has larger effects at the long end than at the short end of the yield curve, limiting the effectiveness of domestic monetary policy to steer the economy since the entire yield curve is relevant for the spending decisions of households and firms. In particular, monetary policy decisions in advanced economies aimed at affecting long-term yields (particularly the term premium), like forward guidance and quantitative easing, spill over to emerging market yields via the term premium (Turner, 2014; Kolasa and Wesołowski, 2020),[41] as well as through the expected future short rate, particularly at the short end due to risk spillovers (Kalemli-Özcan, 2019). Thus, emerging markets remain subject to global risks even when borrowing in local currency (Carstens and Shin, 2019).

[41] Adrian et al. (2019) find that the correlation of the term premia in long-term yields has increased after the global financial crisis. Turner (2014) argues that changes in the U.S. term premium spill over into the term premia of emerging markets.

Comovement of Yields

To assess whether different sections of the yield curves of emerging markets comove more than others, I use one-year rolling correlations of daily yield changes for different maturities.[42] Figure 1.6 displays the results.

The long-term yields of emerging markets are indeed more connected than short-term ones, although local factors remain relevant. Figure 1.6a shows that the long-term yields of emerging markets became more connected after the global financial crisis, and more so since the taper tantrum episode of 2013. For advanced economies, their long-term yields have been more connected among themselves since the beginning of the sample period (see figure 1.6b). On average, the correlation among the long-term yields of emerging markets is less than half that of the yields of advanced economies, suggesting that local investors are relevant holders of medium- and long-term bonds issued by emerging markets. Indeed, even though the share of foreign investors in the LC bonds of emerging markets has increased over time (from 10% in 2008 to 25% in 2019 according to Kolasa and Wesołowski (2020)), the next section shows that local factors are still important drivers for the long end of their yield curves.

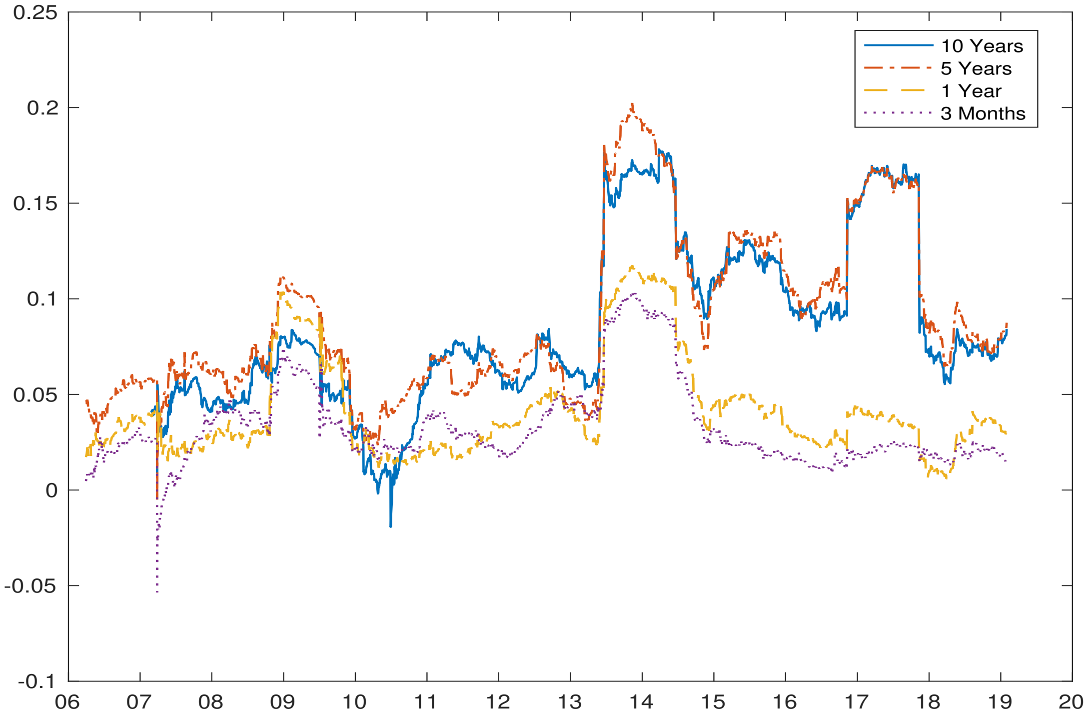
Drivers of Yields

The yield curve channel requires one to distinguish between interest rates at different maturities and calls attention to the role of the U.S. term premium. Here, I assess the role of the components of U.S. yields (the average expected future short rate and the term premium) in explaining emerging market yields and their components at different maturities. In fact, the assessment of the yield curve channel would be limited without the decomposition of U.S. and emerging market yields. For this purpose, I run the following panel regressions

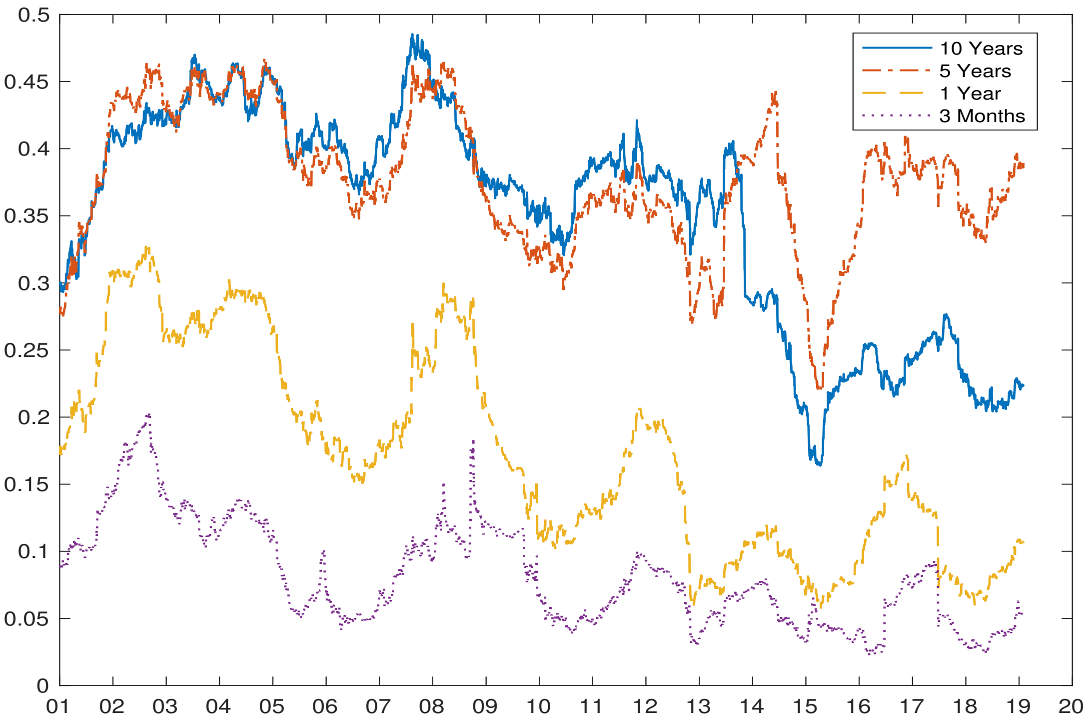
$$y_{i,t} = \alpha_i + \gamma_1' z_{i,t}^1 + \gamma_2' z_{i,t}^2 + u_{i,t}, \tag{1.18}$$

[42] Appendix 1.B reports essentially the same patterns but using the connectedness index of Diebold and Yilmaz (2014) rather than rolling correlations. It also compares the comovement of nominal and synthetic yields, and analyzes the comovement among the components of emerging market yields.

Figure 1.6. Comovement of Yield Curves: Rolling Correlations



(a) Emerging Markets



(b) Advanced Economies

Notes: This figure plots one-year rolling correlation coefficients of daily changes in the nominal yields of emerging markets and advanced economies averaged across all country pairs for the for 10-year (solid line), 5-year (dash-dotted line), 1-year (dashed line), and 3-month (dotted line) maturities.

in which α_i are country fixed effects, $z^1_{i,t}$ is a vector containing the components of the U.S. yield curve, $z^2_{i,t}$ is a vector of global and domestic variables that potentially drive the yields, and $u_{i,t}$ is the error term. The dependent variables $y_{i,t}$ are the nominal yields and their three components for the 10- and 2-year maturities.[43] As before, I use Driscoll–Kraay standard errors to test for significance.[44]

The explanatory variables of interest are the components of U.S. yields, which come from the model of Kim and Wright (2005), who address the small sample problem using survey forecasts of future short rates. I control for the monetary stance and local macroeconomic conditions using the policy rate reported by each country to the Bank for International Settlements, as well as domestic inflation and unemployment rates. Rey (2013) highlights the role of the Cboe Volatility Index (VIX) as an important driver of the global financial cycle, which reflects the implied volatility in stock option prices and is usually seen as a measure of risk aversion and economic uncertainty.[45] Baker et al. (2016) construct a news-based economic policy uncertainty (EPU) index that serves as the basis for the global and U.S. versions,[46] which are used as alternative, and arguably exogenous, measures of global uncertainty. The index of global economic activity proposed by Hamilton (2019) captures real variables. Finally, the exchange rate (LC per USD) is included to rule out explanations of changes in yields based on currency movements; the exchange rate is standardized for each country over the sample period.

Tables 1.4 and 1.5 report the results. The evidence is in line with the yield curve channel.[47] First, the response of the average expected future short rates of emerging markets to the domestic policy rate decreases with maturity and is positively associated with its U.S. counterpart only at the long end, both results are in line with the argument

[43]Kalemli-Özcan (2019) focuses on yields with maturities of 1 year or less. Here, I focus on the 2-year yield because is a benchmark commonly used by market participants. The conclusions based on the 10- and 2-year maturities carry on for the 5- and 1-year maturities, which are reported in appendix 1.C. The 1-year maturity is the shortest one for which the decomposition of U.S. yields used here is available.

[44]The Pesaran test of cross-sectional independence is rejected in all cases at the 1% significance level.

[45]Given the sudden spikes in the index, it is common to use it in logs. For consistency, the other uncertainty indexes are also used in logs.

[46]Although the EPU index has been replicated for different countries, it is only available for five of the emerging markets in the sample: Brazil, Colombia, Mexico, Russia and South Korea.

[47]The tables report the estimates for the full specification of the model. The results are robust to specifications of the model that progressively include the regressors for each dependent variable.

that monetary autonomy is stronger at the short end than at the long end of the curve. Second, the response of the term premia of emerging markets to the U.S. term premium increases with maturity and is positively associated with the VIX only at the long end, both results align with the claim that the U.S. term premium, and the global financial cycle in general, is more relevant for the long end than for the short end of the curve. Third, the U.S. term premium not only influences the yields in emerging markets through its effect on their term premia but through the other components too. In particular, I can directly test the hypothesis of Kalemli-Özcan (2019) regarding risk spillovers to the short rate thanks to the yield decompositions. Risk spillovers to the average expected future short rates of emerging markets indeed decrease with maturity and operate mainly through the U.S. term premium than via the VIX. These conclusions would be different if one fails to account for credit risk given that the term premium and credit risk components would be mixed together.

A glimpse on the drivers of the yields of emerging markets is a byproduct of the analysis on the yield curve channel. For instance, inflation and unemployment are key domestic variables. In particular, the term premium and the credit risk compensation are countercyclical, investors demand higher compensations during recessions, when the unemployment rate increases. Moreover, the positive association between inflation and the term premium conforms with the idea that inflation erodes the value of nominal bonds and so, in periods of rising inflation investors expect the central bank to tighten its monetary stance going forward, demanding a higher term premium. As expected for measures of risk and uncertainty, shifts in the VIX are positively associated with the term premium and credit risk compensation. Also, higher global economic uncertainty induces a flight to quality, whereas higher U.S. economic uncertainty leads to a reduction in the perceived credit quality.[48] Lastly, there is evidence supporting the risk-taking channel of exchange rates,[49] according to which a currency appreciation is associated with easier financial conditions (and compressed sovereign bond spreads) due to balance sheet effects.

[48]The coefficient for the EPU Global index in the expected short rate column is negative, while the coefficient for the U.S. EPU index in the credit risk compensation column is positive.

[49]According to the standard trade-channel effect, an appreciation is contractionary because it discourages exports and stimulates imports, reducing the trade balance.

Table 1.4. Drivers of the Emerging Market 10-Year Nominal Yield and Its Components

	Nominal	E. Short Rate	Term Premium	Credit Risk
U.S. Term Premium	0.97***	0.66***	0.73***	-0.37***
	(0.14)	(0.10)	(0.05)	(0.10)
U.S. E. Short Rate	0.17	0.13*	0.21***	-0.21***
	(0.09)	(0.06)	(0.05)	(0.05)
Local Policy Rate	0.24***	0.50***	-0.20***	-0.03*
	(0.03)	(0.03)	(0.02)	(0.01)
Inflation	15.26***	-1.24	10.01***	5.69***
	(2.27)	(2.70)	(1.99)	(1.48)
Unemployment	23.88***	-1.43	13.16***	10.93***
	(3.43)	(2.74)	(1.25)	(2.11)
LC per USD (Std.)	41.58***	45.82***	9.60***	-10.02**
	(5.74)	(5.04)	(2.25)	(3.27)
Log(Vix)	49.95***	-28.79**	37.61***	41.64***
	(12.63)	(10.24)	(8.12)	(8.96)
Log(EPU U.S.)	7.08	-4.34	0.22	10.64**
	(5.58)	(3.82)	(2.93)	(3.74)
Log(EPU Global)	-61.04**	-37.16**	-21.37*	-7.44
	(20.51)	(11.88)	(8.89)	(9.62)
Global Ind. Prod.	1.16	-0.09	0.71*	0.73
	(1.13)	(0.84)	(0.36)	(0.86)
Fixed Effects	Yes	Yes	Yes	Yes
Lags	4	4	4	4
No. Countries	15	15	15	15
Observations	2194	2194	2194	2194
R^2	0.68	0.72	0.48	0.24

Notes: This table reports the estimated slope coefficients of panel data regressions of the 10-year nominal yield and its components (expected short rate, term premium and credit risk compensation) on selected explanatory variables. The sample includes monthly data for 15 emerging markets starting in 2000:1 and ending in 2019:1. The dependent variables are expressed in basis points. The explanatory variables are the U.S. term premium and the U.S. expected short rate according to Kim and Wright (2005) with the same maturity as the dependent variables, the policy rate, domestic inflation and unemployment, the standardized exchange rate (local currency per USD), the log of the Vix, the log of the U.S. and global economic policy uncertainty indexes based on Baker et al. (2016), the global economic activity index of Hamilton (2019). Driscoll–Kraay standard errors in parenthesis; lag length up to which the residuals may be autocorrelated is indicated. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 1.5. Drivers of the Emerging Market 2-Year Nominal Yield and Its Components

	Nominal	E. Short Rate	Term Premium	Credit Risk
U.S. Term Premium	1.59***	1.57***	0.70***	-0.67***
	(0.22)	(0.22)	(0.13)	(0.19)
U.S. E. Short Rate	-0.03	-0.05	0.08***	-0.08*
	(0.04)	(0.04)	(0.02)	(0.03)
Local Policy Rate	0.64***	0.72***	-0.03	-0.02
	(0.03)	(0.04)	(0.02)	(0.02)
Inflation	8.91***	-0.76	7.97***	3.21
	(2.25)	(3.61)	(2.16)	(1.92)
Unemployment	9.39**	-5.52	4.99**	9.20***
	(2.91)	(2.93)	(1.54)	(1.73)
LC per USD (Std.)	27.18***	38.28***	5.04	-8.47*
	(4.84)	(5.44)	(2.92)	(3.86)
Log(Vix)	46.41***	-28.91*	0.39	76.84***
	(8.16)	(12.45)	(7.85)	(10.79)
Log(EPU U.S.)	8.42*	-2.56	-5.16	13.09***
	(3.82)	(5.04)	(3.00)	(3.74)
Log(EPU Global)	-60.39***	-48.37***	-6.33	-4.15
	(13.69)	(12.20)	(7.54)	(9.71)
Global Ind. Prod.	2.61***	-0.72	-0.01	3.03***
	(0.68)	(0.88)	(0.51)	(0.67)
Fixed Effects	Yes	Yes	Yes	Yes
Lags	4	4	4	4
No. Countries	15	15	15	15
Observations	2194	2194	2194	2194
R^2	0.80	0.74	0.22	0.34

Notes: This table reports the estimated slope coefficients of panel data regressions of the 2-year nominal yield and its components (expected short rate, term premium and credit risk compensation) on selected explanatory variables. The sample includes monthly data for 15 emerging markets starting in 2000:1 and ending in 2019:1. The dependent variables are expressed in basis points. The explanatory variables are the U.S. term premium and the U.S. expected short rate according to Kim and Wright (2005) with the same maturity as the dependent variables, the policy rate, domestic inflation and unemployment, the standardized exchange rate (local currency per USD), the log of the Vix, the log of the U.S. and global economic policy uncertainty indexes based on Baker et al. (2016), the global economic activity index of Hamilton (2019). Driscoll–Kraay standard errors in parenthesis; lag length up to which the residuals may be autocorrelated is indicated. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

However, here it works through the expected future short rate and the term premium rather than through the credit risk compensation as reported by Hofmann et al. (2019).

So far, the yield decompositions have been valuable to assess the validity of the yield curve channel and understand the driving forces behind the sovereign yields of emerging markets. Yet the specification in equation (1.18) may suffer from econometric problems such as persistent variables, reverse causality and omitted variables. Moreover, the measures of comovement are unconditional, so not specifically driven by monetary policy surprises.

1.5.2 Identification of Monetary Policy Surprises

Surprises in monetary policy decisions are identified using intraday data on asset prices around Fed's monetary policy announcements in order to capture changes in the information set of market participants. Asset price changes are calculated from 15 minutes before to 1 hour and 45 minutes after each Federal Open Market Committee (FOMC) meeting since 2000 giving a total of 162 events.[50] The surprises are set to zero in non-announcement days. Neither minute releases nor speeches by Fed officials are included.

Gürkaynak et al. (2005) and Swanson (2018) show that monetary policy has more than one dimension. Asset prices respond to different types of news about monetary policy. Following Rogers et al. (2018), I consider three separate types of U.S. monetary policy surprises, referred to hereinafter as target, forward guidance and asset purchase surprises. Target surprises are equal to the change in the yield on the current- or next-month federal funds futures contracts, as proposed by Kuttner (2001). Forward guidance surprises are equal to the residual from regressing the yield change for the 8-quarters ahead Eurodollar futures contract onto the target surprise.[51] Asset purchase surprises are equal to the residual from regressing the yield change in the 10-year Treasury futures contract onto the target and forward guidance surprises. By construction, the three types of surprises are uncorrelated. Positive values in any of the surprises represent a tightening

[50]Following Gürkaynak et al. (2005), I exclude the meeting of September 2001.

[51]The 4-quarters ahead Eurodollar futures contract could also be used, but intraday changes in that contract were essentially zero after 2011 since market participants expected no change in the policy rate for at least a year. Eurodollar futures contracts are bets on the future level of 3-month interest rates.

of the monetary policy stance, and vice versa.

The relevance of the surprises has varied over time. After 2008, there were no changes in the current policy rate until December 2015, so target surprises were essentially zero during that period. Meanwhile, asset purchase surprises are considered starting in October 2008 because their meaning is unclear before that date. Forward guidance surprises have nevertheless been relevant before and after the global financial crisis. Table 1.C.3 in the appendix reports descriptive statistics for the three types of surprises. In general, the Fed has been more aggressive in stimulating than in contracting the U.S. economy, since easing surprises are larger on average and more common than tightening surprises.

1.5.3 The Effects on Emerging Market Yields

The transmission of U.S. monetary policy to the yields of emerging markets is assessed using panel local projections for the daily changes in the yields.[52] While event studies report the response of the variables on the day of a surprise, local projections additionally provide the responses over subsequent periods. It is important to be able to capture the persistence in the response of emerging market yields given the pervasive post-announcement drift in the bond markets of advanced economies documented by Brooks et al. (2019). In addition, I leverage on the yield decompositions at the daily frequency to better understand the transmission of Fed's decisions to the yields.

Specifically, I run the following panel local projections:

$$y_{i,t+h} - y_{i,t-1} = \alpha_{h,i} + \sum_{j=1}^{3} \beta_h^j \epsilon_t^j + \gamma_h \Delta y_{i,t-1} + \eta_h s_{i,t-1} + u_{i,t+h}, \tag{1.19}$$

in which h indicates the horizon (in days) with $h = 0, 1, \ldots, 45$ and each ϵ_t^j represents one of the three types of monetary policy surprises.[53] The regressions include country fixed effects $\alpha_{h,i}$, a lag of the dependent variable,[54] and a lag of the exchange rate $s_{i,t-1}$. The

[52] Jordà (2005) advocates the use of local projections as an alternative to VAR models in order to generate impulse responses that are robust to misspecification. See Hofmann et al. (2019) and Adrian et al. (2019) for recent applications of panel local projections.

[53] There is no need to control for past or future surprises since, by definition, they are unanticipated by the market. On the other hand, even though the types of surprises are uncorrelated by construction, the estimation is more efficient when all the surprises are included simultaneously.

[54] As argued by Hofmann et al. (2019), the large number of daily observations reduces the potential for

regressions are ran for the 10- and 2-year nominal yields and each of their components. The confidence bands are constructed using Driscoll–Kraay standard errors, which allow for time and cross-sectional dependence.

The parameters of interest, β_h^j, measure the average response of the nominal yield (or its components) to monetary policy surprise j at horizon h. The contemporaneous effects (when $h = 0$) are indicated with an arrow in the figures below. All responses are assessed relative to a one basis point reduction (an easing) in any of the surprises, since the Fed has been more aggressive in that direction over the sample period.

The response of U.S. yields and their components to the three surprises serves as a benchmark to assess the responses of the yields of emerging markets. As before, U.S. yields come from the dataset of Gürkaynak et al. (2007), and the components come from the decomposition proposed by Kim and Wright (2005). The responses are reported in figures 1.D.4 to 1.D.7 in the appendix. They are consistent with the findings in the existing literature. For instance, target easing surprises reduce yields, mainly driven by a decline in the average expected future short rates; while forward guidance and asset purchase easing surprises decrease yields, in part due to a reduction in the term premium.

Target Surprises

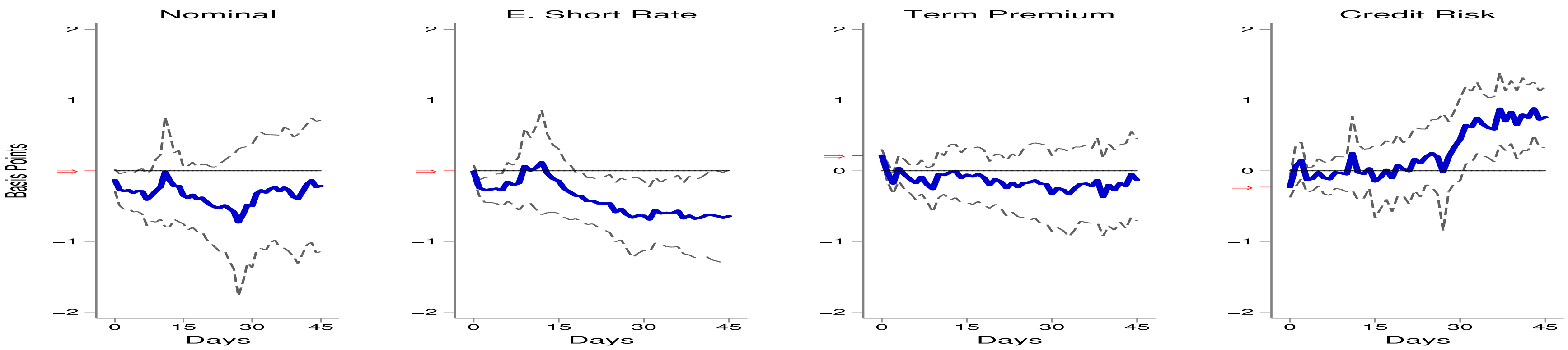
Figure 1.7 shows the response of emerging market yields to a target easing surprise. Although the magnitude of the contemporaneous yield response is lower than in the U.S., it builds over time. This delayed response is documented by Brooks et al. (2019) for the U.S. and by Adrian et al. (2019) for a sample comprised mostly of advanced economies,[55] which they attribute to a portfolio rebalancing channel. Moreover, the reaction to forward guidance and asset purchase surprises is also sluggish, as discussed later. Therefore, slow-moving capital is also present in the bonds of emerging markets.[56]

Nickell bias that arises by including a lagged dependent variable in panel regressions with fixed effects and small time dimensions. Indeed, the impulse responses reported here are essentially the same when the lag of the dependent variable is excluded.

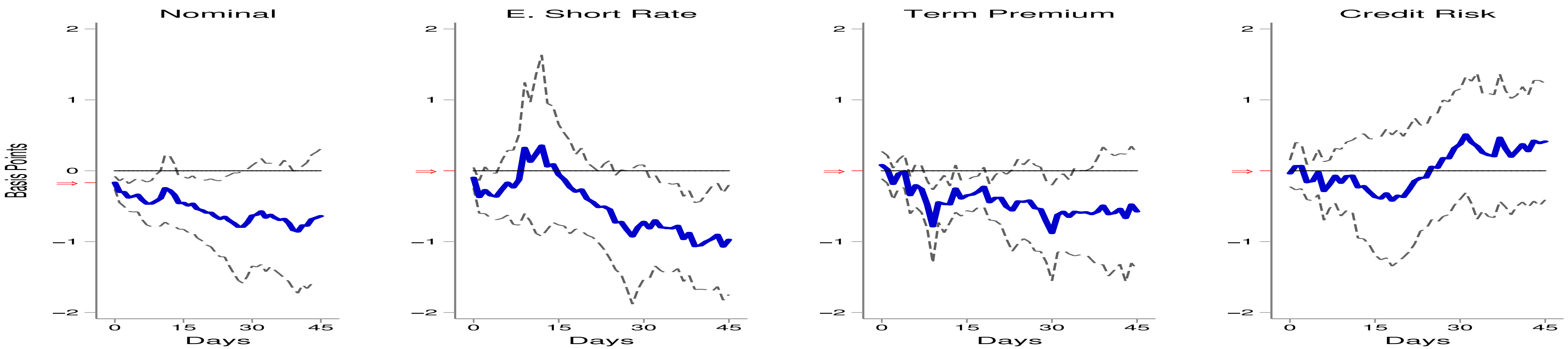
[55] It is also seen in the responses of U.S. yields reported in appendix D. Although the U.S. Treasuries market is deep and liquid, some players like pension funds and foreign investors might respond gradually.

[56] Figure 1.D.10 in the appendix shows that the delayed responses are not driven by the response of the forward premium, the term added to the U.S. yield curve to construct the synthetic yields.

Figure 1.7. Response of the Yield Curve to a Target Surprise



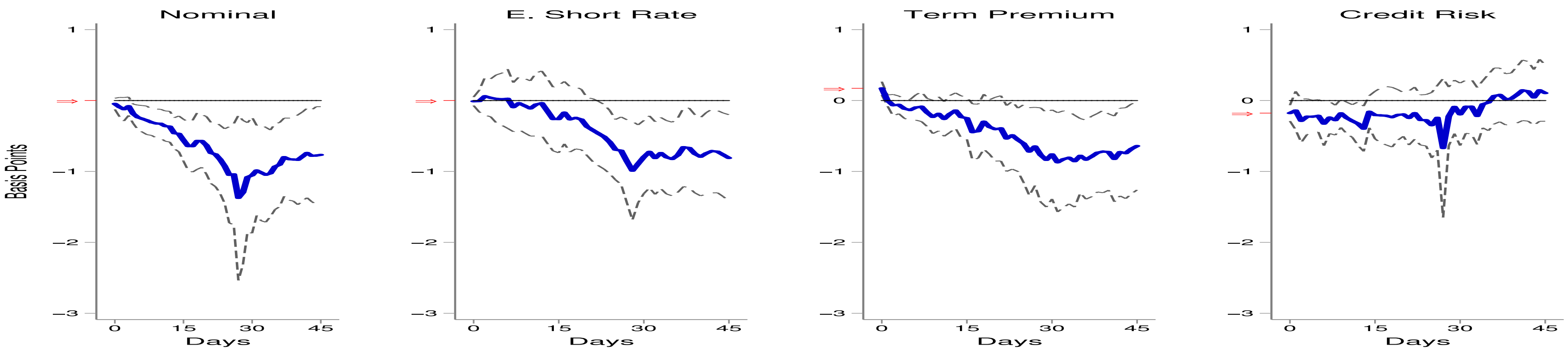
(a) 10-Year Yield



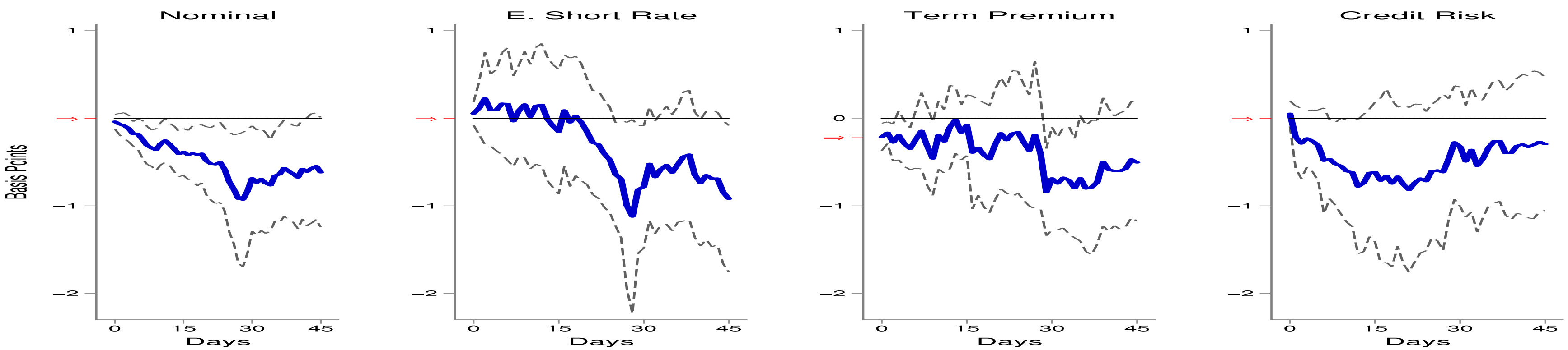
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year emerging market nominal yields and their components to a target easing surprise of 1 basis point. Nominal yields are decomposed into an expected future short-term interest rate, a term premium and credit risk compensation, see section 1.4 for details. Target surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.8. Response of the Yield Curve to a Forward Guidance Surprise: 2000-2008



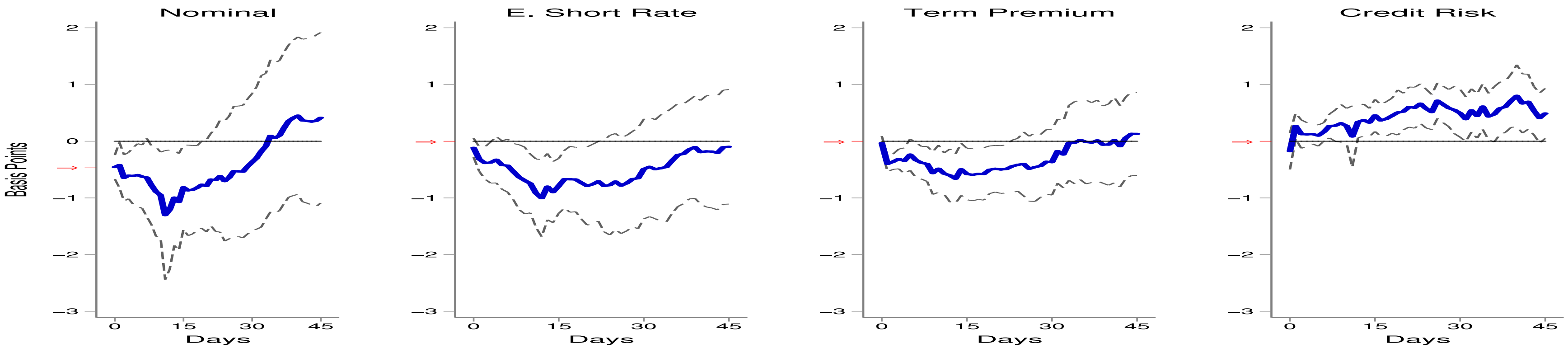
(a) 10-Year Yield



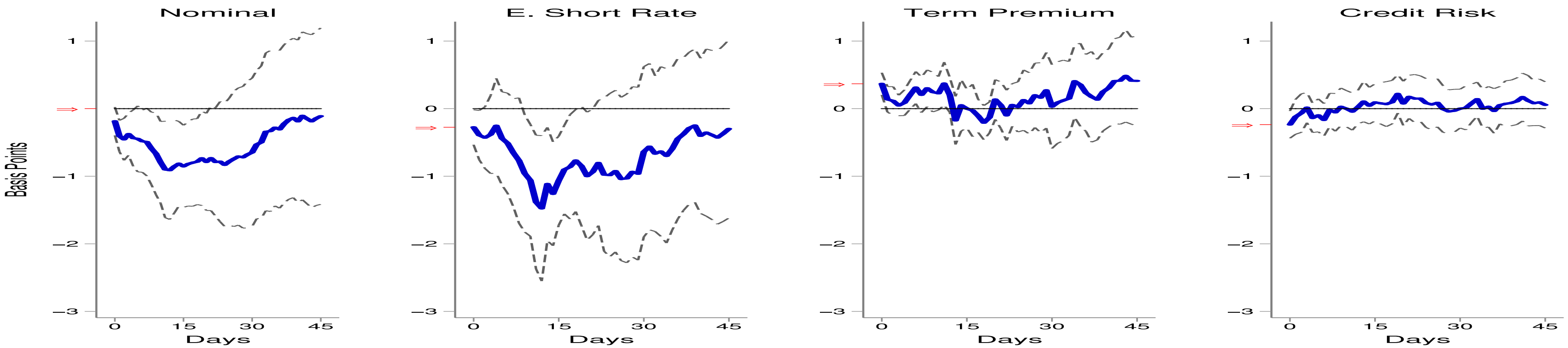
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year emerging market nominal yields and their components to a forward guidance easing surprise of 1 basis point. Nominal yields are decomposed into an expected future short-term interest rate, a term premium and credit risk compensation, see section 1.4 for details. Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.9. Response of the Yield Curve to a Forward Guidance Surprise: 2008-2019



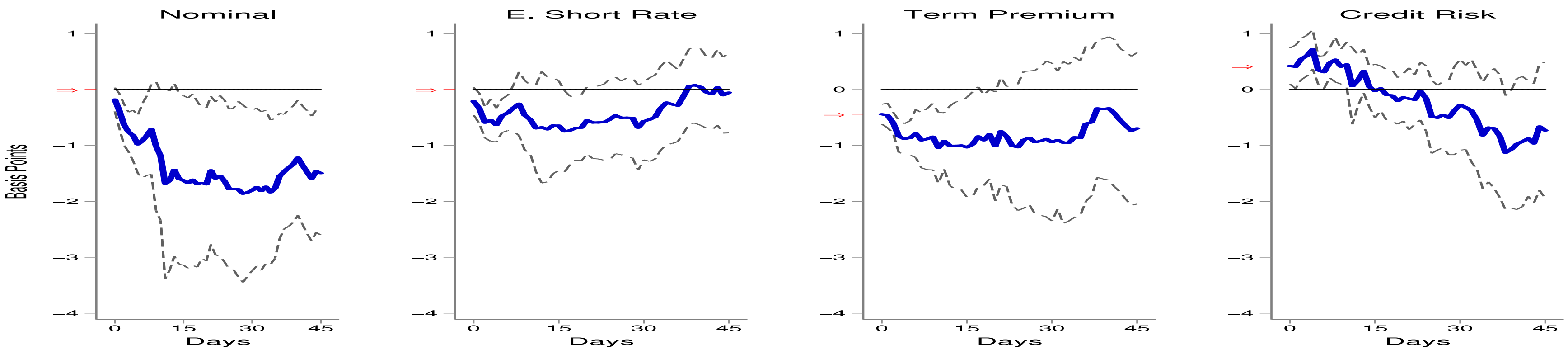
(a) 10-Year Yield



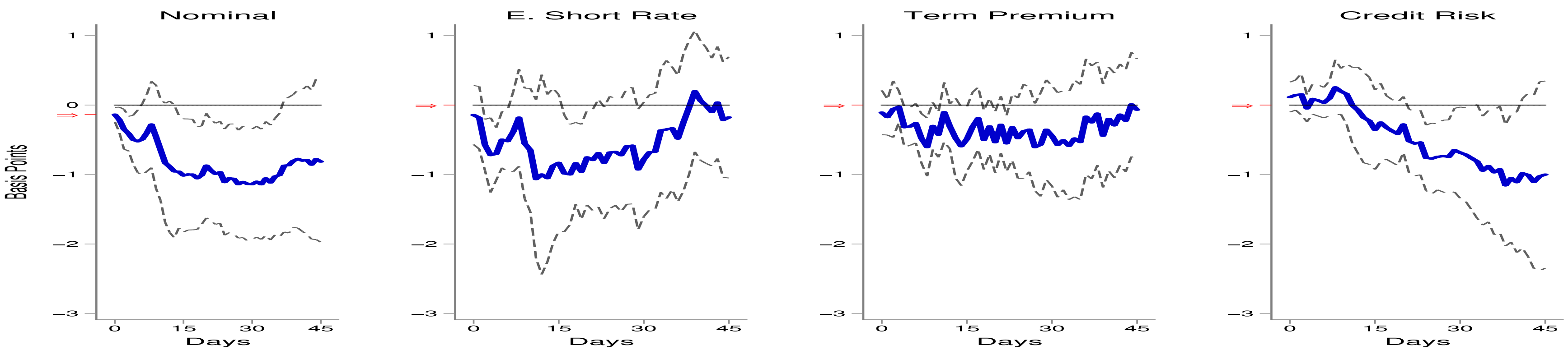
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year emerging market nominal yields and their components to a forward guidance easing surprise of 1 basis point. Nominal yields are decomposed into an expected future short-term interest rate, a term premium and credit risk compensation, see section 1.4 for details. Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.10. Response of the Yield Curve to an Asset Purchase Surprise



(a) 10-Year Yield



(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year emerging market nominal yields and their components to an asset purchase easing surprise of 1 basis point. Nominal yields are decomposed into an expected future short-term interest rate, a term premium and credit risk compensation, see section 1.4 for details. Asset purchase surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Looking at the effects of a target easing surprise on the yield components in figure 1.7, investors expect central banks in emerging markets to follow the monetary stance of the Fed as can be seen in the decline of the expected future short rate, particularly at the short end; in fact, most of the effect is reflected on that component. Note that there is no effect on the credit risk compensation at the short end and there is essentially no effect on the term premia. However, the credit risk compensation at the long end increases one month after the surprise. Mechanically, both the nominal and synthetic yield curves steepen (since short rates decline) but in a way that the long end of the synthetic yield curve declines by more than the nominal one, and so borrowing (long-term) synthetically in LC becomes cheaper; equivalently, the opportunity cost of lending (long-term) directly in LC increases. As a result, the nominal-synthetic spread at the long end rises (by almost one-to-one) in the month following the surprise. Intuitively, loose financial conditions abroad trigger a 'reach for yield' behavior among investors (Hausman and Wongswan, 2011) that can incentivize more borrowing in emerging markets by sovereigns in local currency (Bigio et al., 2018) and by corporates in foreign currency[57]. In either case, the price of default risk (not necessarily the risk itself) increases. This effect can be seen as a fiscal implication in emerging markets of Fed's monetary policies. Credit risk compensation is thus an important factor to understand the transmission of U.S. monetary policy to emerging market yields.

In sum, economically significant spillovers from target easing surprises build over time reducing the expected future short rate and increasing the long term credit risk compensation of emerging markets, so U.S. monetary policy spillovers do not need to involve the term premium. So far, the potential fiscal implications for emerging markets of Fed's monetary policies have not been discussed in the literature.

Forward Guidance Surprises

Since U.S. monetary policy spillovers to long-term yields increased after the global financial crisis (Albagli et al., 2019), figures 1.8 and 1.9 display the responses of emerging

[57] Du and Schreger (2017) show that higher reliance on foreign currency borrowing by corporates increases sovereign default risk in emerging markets.

market yields to a forward guidance easing surprise before and after October 2008, respectively.

Before the global financial crisis, a forward guidance easing surprise led to a downward parallel shift in the yield curves of emerging markets in the month following the surprise. The effect on emerging market yields lasted longer than on U.S. yields, and was generally driven by a decline in all three components; at the long end, it was especially through a decline in the expected short rate and the term premium. In this sense, investors expected central banks in emerging markets to follow the Fed's monetary stance.

After the global financial crisis, the transmission of forward guidance easing surprises changed. The decline in the nominal yields of emerging markets at the long end lasts less than in long-term U.S. yields. Therefore, the nominal yield curve in emerging markets steepens relative to the U.S. yield curve in the month following the surprise, so the nominal-synthetic spread in emerging market yields widens at the long end. The intuition is similar to the one for target surprises above. A loose future path of the U.S. policy rate trigger a 'reach for yield' behavior among investors and might incentivize more borrwing in emerging markets by sovereigns in local currency and/or by corporates in foreign currency, which increases the price of default risk.

Moreover, the response of the term premia at the long end is similar in emerging markets than in the U.S. By making announcements about the future path of the federal funds rate, the Fed attempts to reduce long-term U.S. yields mainly by reducing the term premium (see figure 1.D.6). Figure 1.9 shows that those announcements also reduce the term premia in emerging market yields at the long end. This is where accounting for credit risk pays off because if it were to be ignored, one would incorrectly conclude that forward guidance does not affect the term premia in emerging markets. The reason is that the 'clean' term premium and the credit risk compensation components respond in opposite directions with magnitudes that almost offset each other, so there is no net effect in the term premium contaminated with credit risk.

In relation to the yield curve channel, a forward guidance easing surprise not only reduces the term premia at the long end but also the expectation for the policy rate at the short end, which supports the risk spillovers mechanism in Kalemli-Özcan (2019).

Asset Purchase Surprises

Figure 1.10 shows that an asset purchase easing surprise flattens the yield curve in emerging markets, similar to the effect on the U.S. yield curve (see figure 1.D.7). In both cases, the effect at the long end is larger than at the short end. The on-impact response of U.S. yields is larger, whereas the response of the nominal yields of emerging markets lasts longer. These two effects in turn explain the response of the credit risk compensation at the long end, which initially increases followed by a sluggish and considerable decline. The counterintuitive initial increase is more a reflection of the response in the U.S. Treasuries market than on the bond markets in emerging economies. Indeed, an asset purchase easing surprise triggers a strong investor reaction in the U.S. Treasuries market, leading to a more than one-to-one on-impact decline in the long-term U.S. yield (see figure 1.D.7a). The eventual decline in the credit risk compensation as well as the reduction in the term premium reflect a relaxation of global financial conditions, so investors are more willing to buy the long-term debt of emerging markets.

In terms of the yield curve channel, an asset purchase easing surprise reduces the term premia at the long end and the expectation for the policy rate at the short end, similar to the effect of a forward guidance easing surprise after 2008. These results show up in figures 1.9 and 1.10 but not in figures 1.7 and 1.8, so the yield curve channel is a relatively recent phenomenon that coincides with the implementation of unconventional monetary policies by the Fed after the global financial crisis. Those policies transmit to emerging market yields through their different components, thus limiting the influence central banks in emerging markets can exert over their domestic yield curves.

1.6 Concluding Remarks

This paper decomposes the sovereign yields of 15 emerging markets taking into account the credit risk embedded in them, and empirically quantifies the transmission channels of U.S. monetary policy to them. Emerging market nominal yields are decomposed into average expected future short rates, a term premium and compensation for credit risk.

The responses to target, forward guidance and asset purchase surprises are sluggish but amplify over time. In addition, surprises in Fed's policy decisions lead to a reassessment of policy rate expectations and a repricing of interest rate risk as well as of credit risk in emerging markets. The effect on credit risk has not been explored before and it is a prospective area for future research. Lastly, since the global financial crisis, U.S. monetary policy has spilled over to emerging markets through a yield curve channel, which limits their monetary autonomy along their yield curves. The results in this paper show that, in order to adequately characterize the transmission channels of U.S. monetary policy, it is important to explicitly account for credit risk in the local currency debt of emerging markets and to examine the effects at different maturities.

The results presented here can be extended in several directions. The proposed three-part decomposition of emerging market yields has many applications, such as analyzing the transmission of monetary policy domestically and further decomposing each part (e.g. average expected short rates can be split into inflation and real interest rate expectations). The results might also inform theoretical models for pricing sovereign defaultable bonds. Finally, surprises from other central banks in advanced economies can be included in the analysis of monetary policy spillovers.

Appendix 1.A A Proxy for Long-Term Inflation Forecasts

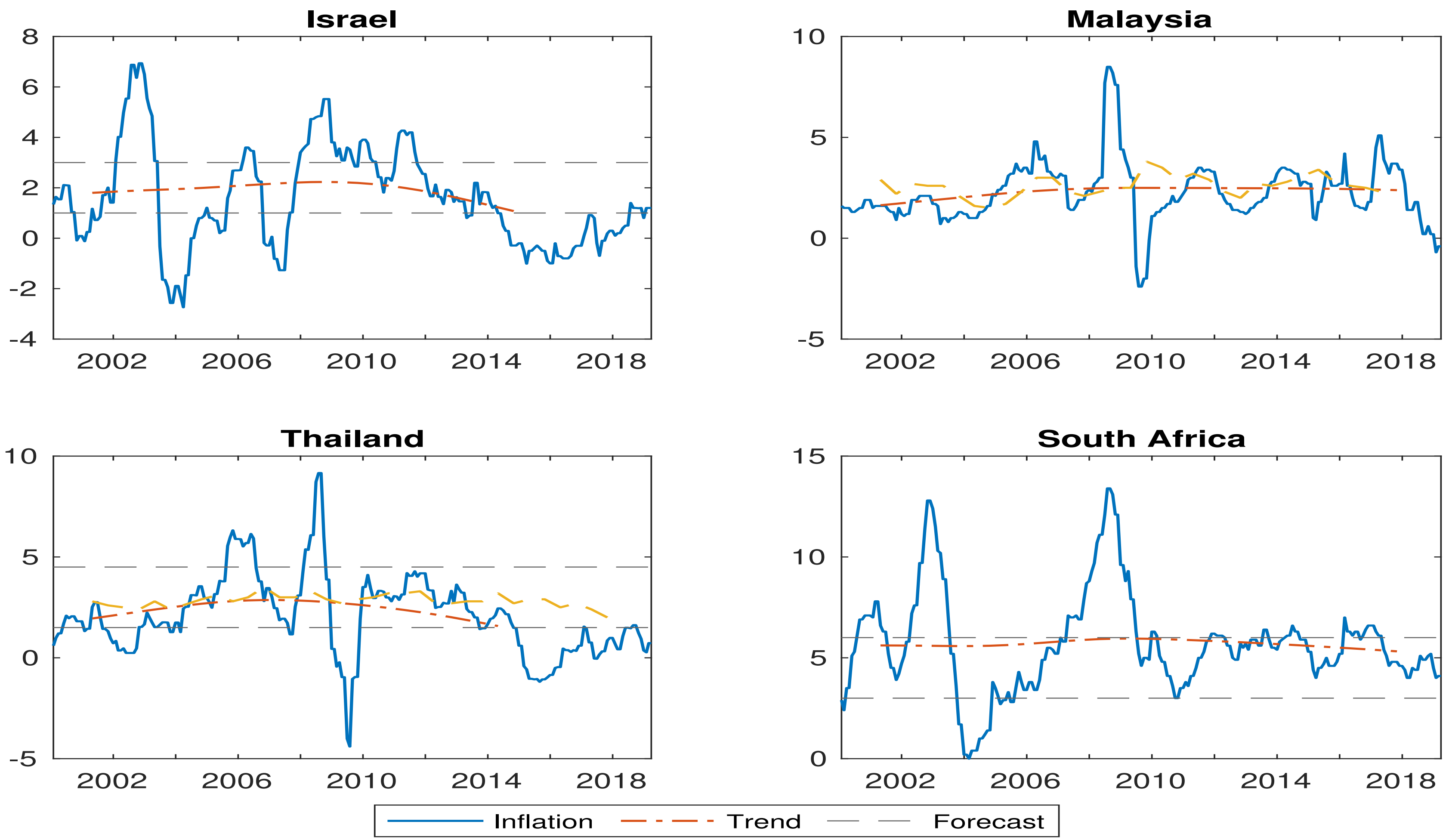
An advantage of the small open economy approach to infer long-term forecasts for the short rate is that, for emerging markets, it only requires data on inflation forecasts, or a proxy in the case of countries with no long-term forecasts available as is the case for Israel and South Africa.

Inflation expectations are hoped to match measures of inflation that exclude unexpected shocks and better reflect the inflation environment. Different measures of core inflation exist. I use the inflation trend obtained by applying the Hodrick–Prescott filter to the series of realized inflation of each country.

There are two main concerns for using this approach. Namely, the filter is sensitive to the sample period used and the resulting trend can be outside of the target inflation band due to the innate dynamics of the series, which would be at odds with survey data (see figure 1.1). In the case of Israel and South Africa, however, there is no marked upward or downward trend in their inflation during the sample period. Therefore, for both countries, trend inflation is calculated for the whole period for which survey data is available for the rest of the countries in the sample, and as long as the resulting trend is within the respective inflation target band.

Figure 1.A.1 shows the realized and trend inflation for Israel and South Africa along with those of Malaysia and Thailand, two countries with a similar pattern for inflation (i.e. no marked upward or downward trend) and for which survey data is available. The figure shows that trend inflation seems to be a good proxy for the long-term inflation forecasts in Malaysia and Thailand. Also, as can be seen in the main text (figure 1.1), 5-year and long-term inflation forecasts follow each other closely, therefore trend inflation is used as the proxy for both the 5-year and the long-term inflation forecasts in the case of Israel and South Africa.

Figure 1.A.1. Inflation Trend and Long-Horizon Forecast for Inflation



Notes: This figure plots consumer price inflation (solid line), inflation trend based on the Hodrick–Prescott filter (dash-dotted line) and long-term inflation forecast (dashed line). The figure also includes the upper and lower bounds for the domestic inflation target. The upper and lower bounds are the most recent ones for each country.

Appendix 1.B Connectedness of Yields

An alternative approach to rolling correlations for assessing the comovement of yields is the connectedness index of Diebold and Yilmaz (2014). The index assesses shares of forecast error variation in a country's bond market due to shocks arising elsewhere.[58] Higher numbers (between 0 and 100%) indicate a higher degree of comovement. Figure 1.B.1 exhibits the same patterns as those reported in figure 1.6 using rolling correlations.

Figure 1.B.2a compares the index for the nominal and synthetic yields of emerging markets with the nominal yields of advanced economies. The relatively low connectedness among the yields of emerging markets supports estimating the term structure models for their yield curves separately rather than jointly. More generally, the evidence of highly connected yields in advanced economies and low connected yields in emerging markets is consistent with global bond markets operating under a core-periphery structure, in which the bond markets of advanced economies constitute the (highly interconnected) core and those of emerging markets represent the (less connected) periphery who are in turn connected to the network mainly through countries in the core.[59] According to this view, shocks to emerging market yields are mainly idiosyncratic—reflected in less comovement among themselves—so what matters for them are not spillovers originating in other emerging markets but in advanced economies.

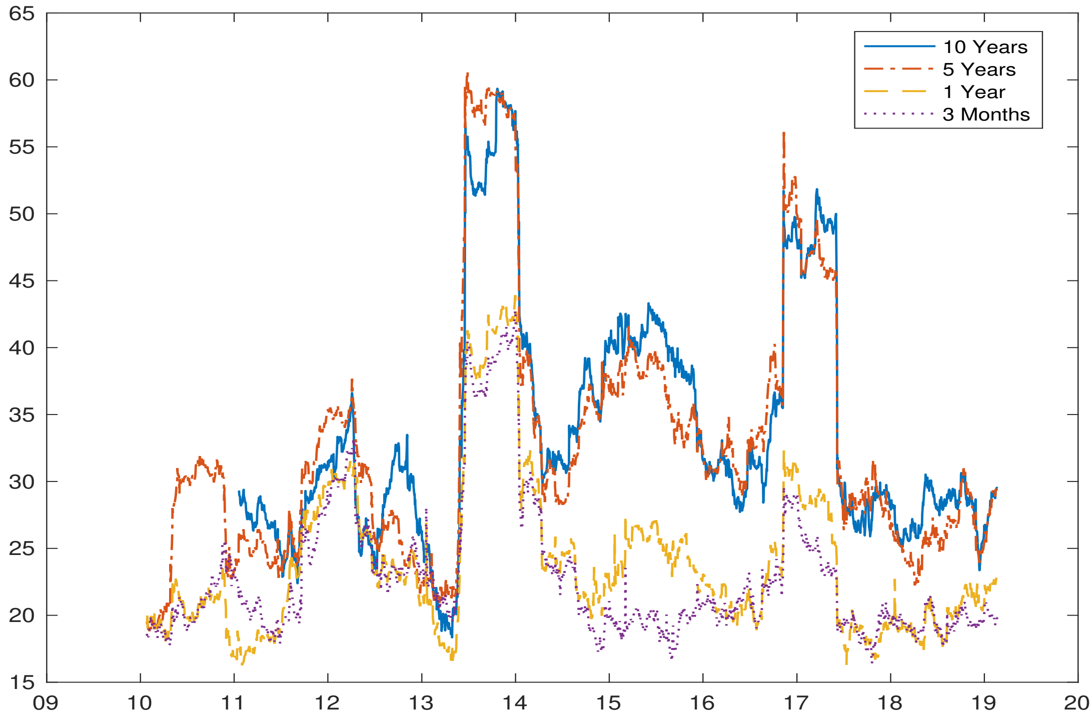
Figure 1.B.2b shows the connectedness index for the components of emerging market yields. From all three components of emerging market yields, the term premium has been slightly more connected since the taper tantrum in 2013 with the expected future short rate becoming more connected towards the end of the sample.[60] Meanwhile, the credit risk compensation has been essentially the least connected component. Figure 1.B.2a shows that the level of the index for synthetic yields tends to be higher than that for nominal yields, which supports that the credit risk component is more idiosyncratic.

[58]Following Adrian et al. (2019) and Bostanci and Yilmaz (2020), I compute the index using a VAR(1), with a forecast horizon of 10 days and a rolling window of 150 days for the daily changes of yields.

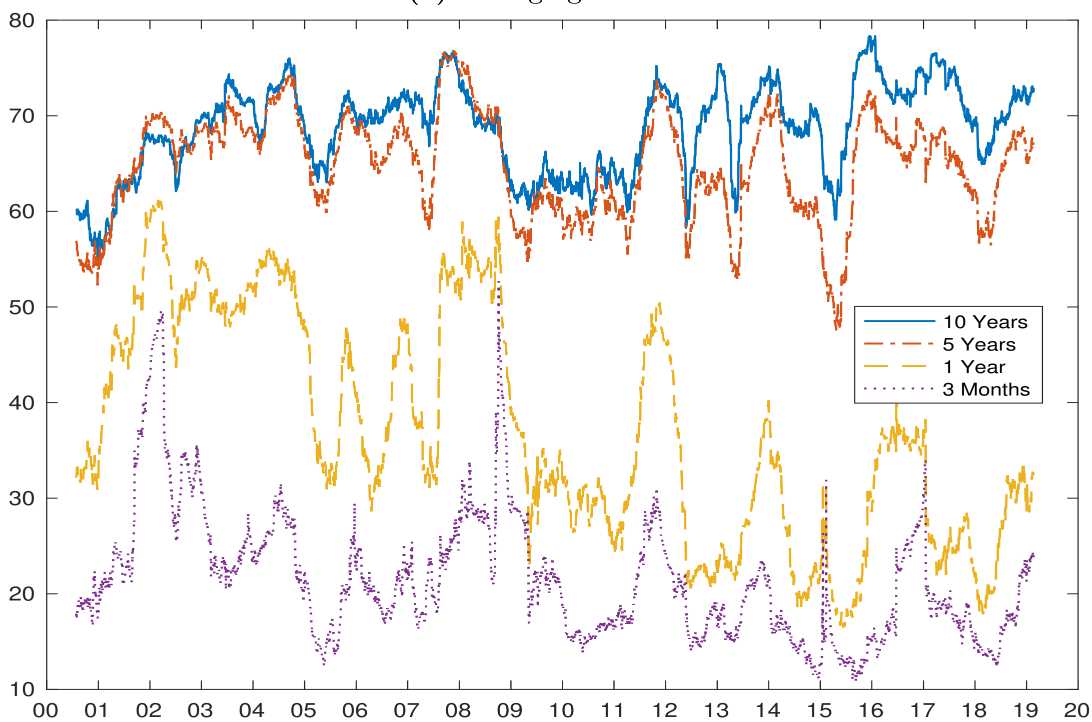
[59]The core-periphery structure has been shown to be a good description of different networks in economics and finance. Craig and von Peter (2014), for example, show that the interbank market operates under such a structure.

[60]Adrian et al. (2019) show that the increase in the connectedness among the yields of advanced economies has been driven by an increase in the connectedness of their term premia.

Figure 1.B.1. Comovement of Yield Curves: Connectedness Index



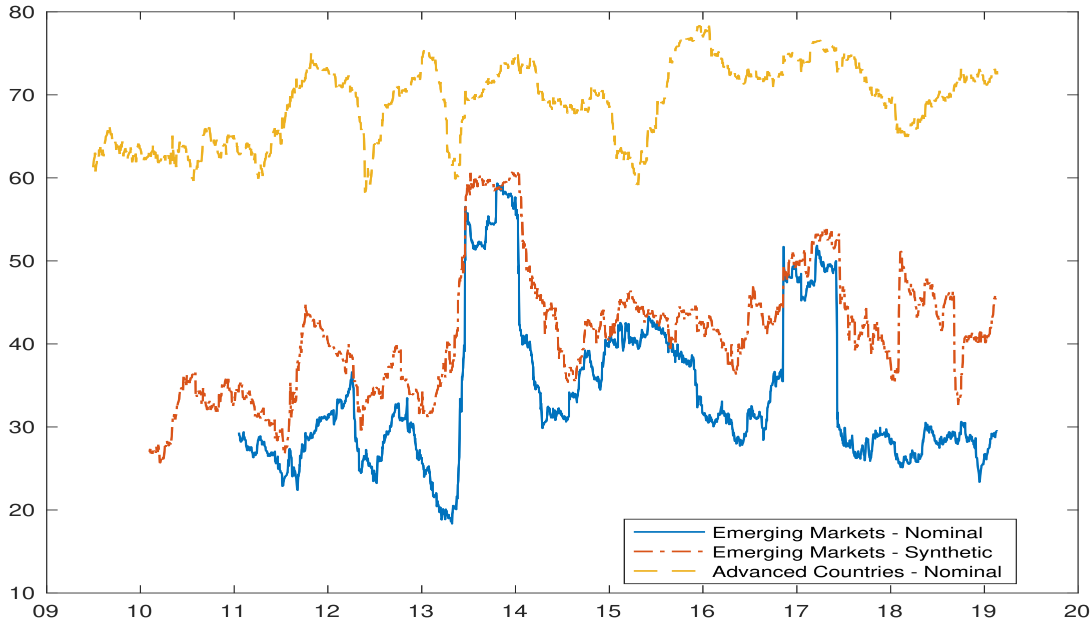
(a) Emerging Markets



(b) Advanced Economies

Notes: This figure plots the connectedness index of Diebold and Yilmaz (2014) for the nominal yields of emerging markets and advanced economies for different maturities: 10 years (solid line), 5 years (dash-dotted line), 1 year (dashed line), and 3 months (dotted line). The index is obtained using a vector autoregression of order 1, with a forecast horizon of 10 days and a rolling window of 150 days for the daily changes of the nominal yields at each maturity.

Figure 1.B.2. Connectedness of 10-Year Yields and Components



(a) Nominal and Synthetic Yields

(b) Nominal Yield Components

Notes: This figure plots the connectedness index of Diebold and Yilmaz (2014) for 10-year yields. Panel (a) compares the connectedness index of nominal (solid line) and synthetic (dash-dotted line) yields of emerging markets and the nominal (dashed line) yields of advanced economies. Panel (b) compares the connectedness index of each component of the nominal yields of emerging markets: the expected future short rate (solid line), the term premium (dash-dotted line) and the credit risk compensation (dashed line). The index is obtained using a vector autoregression of order 1, with a forecast horizon of 10 days and a rolling window of 150 days for the daily changes of the 10-year yields and their components. The index for some components has a shorter history because its computation requires a balanced panel and the components do not start on the same date (e.g. the construction of the synthetic curves does not involve nominal yields).

Appendix 1.C Supplementary Tables

Table 1.C.1. Drivers of the Emerging Market 5-Year Nominal Yield and Its Components

	Nominal	E. Short Rate	Term Premium	Credit Risk
U.S. Term Premium	1.27***	1.03***	0.77***	-0.53***
	(0.17)	(0.13)	(0.06)	(0.13)
U.S. E. Short Rate	0.04	0.03	0.11**	-0.12***
	(0.06)	(0.04)	(0.03)	(0.04)
Local Policy Rate	0.41***	0.60***	-0.15***	-0.02
	(0.03)	(0.04)	(0.02)	(0.02)
Inflation	12.34***	-0.93	8.69***	4.41**
	(2.33)	(3.20)	(1.93)	(1.61)
Unemployment	18.56***	-3.62	10.57***	11.10***
	(3.11)	(2.81)	(1.28)	(2.05)
LC per USD (Std.)	33.70***	40.88***	4.06	-8.17*
	(5.28)	(5.06)	(2.52)	(3.28)
Log(Vix)	57.66***	-29.44*	25.78***	61.95***
	(9.95)	(11.34)	(7.19)	(9.69)
Log(EPU U.S.)	8.97	-3.58	-0.13	10.86**
	(4.88)	(4.27)	(2.92)	(3.58)
Log(EPU Global)	-66.11***	-40.05***	-19.45*	-8.35
	(16.52)	(11.80)	(8.06)	(9.52)
Global Ind. Prod.	2.32**	-0.41	0.90*	1.86*
	(0.84)	(0.83)	(0.38)	(0.75)
Fixed Effects	Yes	Yes	Yes	Yes
Lags	4	4	4	4
No. Countries	15	15	15	15
Observations	2194	2194	2194	2194
R^2	0.74	0.73	0.37	0.30

Notes: This table reports the estimated slope coefficients of panel data regressions of the 5-year nominal yield and its components (expected short rate, term premium and credit risk compensation) on selected explanatory variables. The sample includes monthly data for 15 emerging markets starting in 2000:1 and ending in 2019:1. The dependent variables are expressed in basis points. The explanatory variables are the U.S. term premium and the U.S. expected short rate according to Kim and Wright (2005) with the same maturity as the dependent variables, the policy rate, domestic inflation and unemployment, the standardized exchange rate (local currency per USD), the log of the Vix, the log of the U.S. and global economic policy uncertainty indexes based on Baker et al. (2016), the global economic activity index of Hamilton (2019). Driscoll–Kraay standard errors in parenthesis; lag length up to which the residuals may be autocorrelated is indicated. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 1.C.2. Drivers of the Emerging Market 1-Year Nominal Yield and Its Components

	Nominal	E. Short Rate	Term Premium	Credit Risk
U.S. Term Premium	1.87***	2.06***	0.54**	-0.73*
	(0.38)	(0.41)	(0.20)	(0.31)
U.S. E. Short Rate	-0.01	-0.04	0.07***	-0.07*
	(0.04)	(0.04)	(0.02)	(0.03)
Local Policy Rate	0.73***	0.80***	0.02	-0.04
	(0.03)	(0.04)	(0.02)	(0.02)
Inflation	7.48**	-0.92	7.75***	3.83*
	(2.30)	(3.78)	(2.20)	(1.67)
Unemployment	4.98	-6.51*	1.47	8.29***
	(2.81)	(3.03)	(1.75)	(1.42)
LC per USD (Std.)	28.41***	38.98***	7.24*	-7.46
	(4.61)	(5.64)	(3.20)	(4.08)
Log(Vix)	33.84***	-29.80*	-8.86	80.67***
	(7.50)	(12.81)	(7.83)	(11.03)
Log(EPU U.S.)	4.71	-3.02	-8.54**	12.41**
	(3.36)	(5.84)	(2.69)	(3.99)
Log(EPU Global)	-50.90***	-47.85***	3.45	-5.26
	(12.55)	(12.57)	(7.40)	(9.52)
Global Ind. Prod.	2.28**	-1.21	-1.10*	3.47***
	(0.77)	(1.00)	(0.53)	(0.63)
Fixed Effects	Yes	Yes	Yes	Yes
Lags	4	4	4	4
No. Countries	15	15	15	15
Observations	2194	2194	2194	2194
R^2	0.82	0.74	0.20	0.31

Notes: This table reports the estimated slope coefficients of panel data regressions of the 1-year nominal yield and its components (expected short rate, term premium and credit risk compensation) on selected explanatory variables. The sample includes monthly data for 15 emerging markets starting in 2000:1 and ending in 2019:1. The dependent variables are expressed in basis points. The explanatory variables are the U.S. term premium and the U.S. expected short rate according to Kim and Wright (2005) with the same maturity as the dependent variables, the policy rate, domestic inflation and unemployment, the standardized exchange rate (local currency per USD), the log of the Vix, the log of the U.S. and global economic policy uncertainty indexes based on Baker et al. (2016), the global economic activity index of Hamilton (2019). Driscoll–Kraay standard errors in parenthesis; lag length up to which the residuals may be autocorrelated is indicated. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

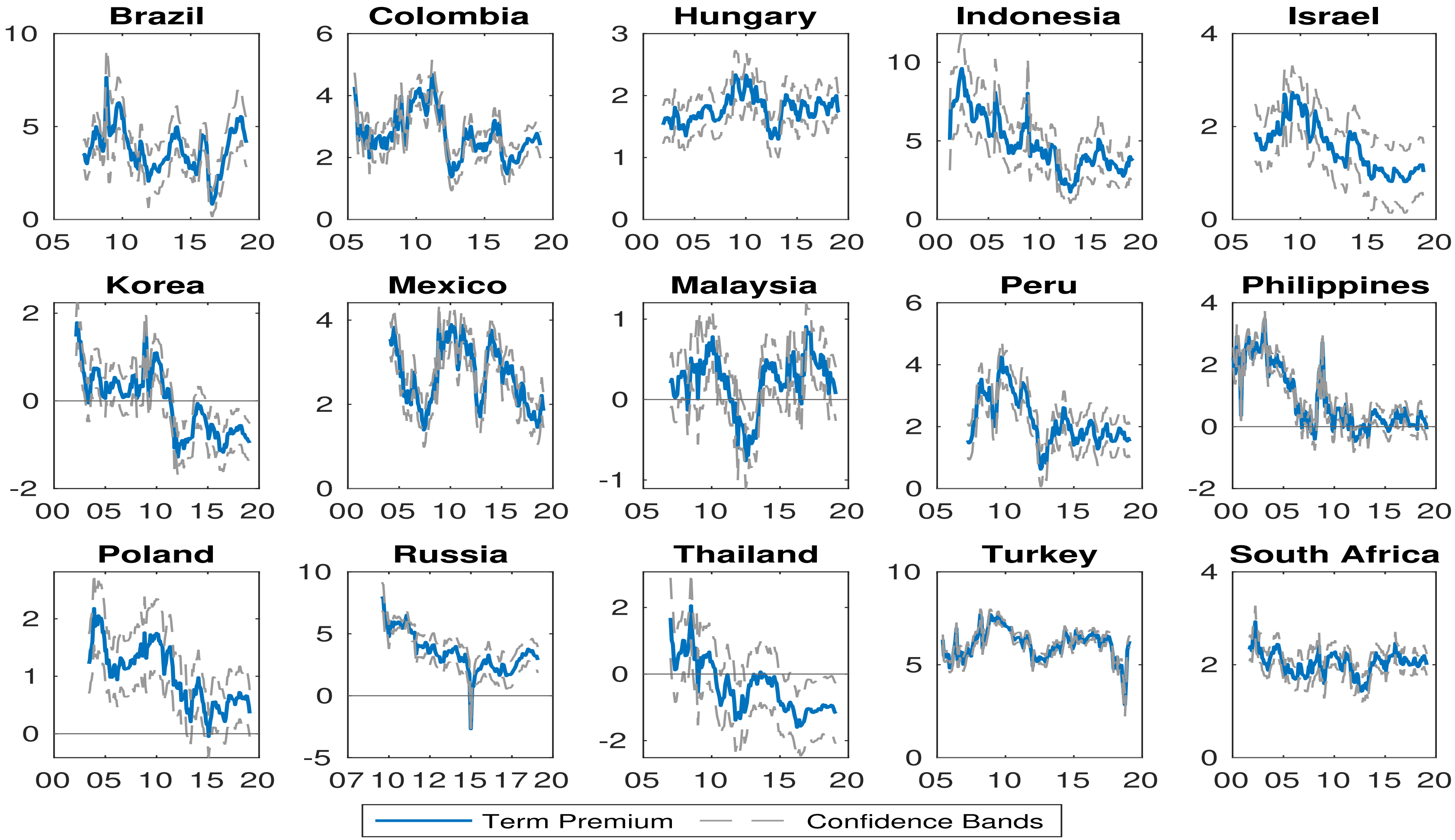
Table 1.C.3. Descriptive Statistics of U.S. Monetary Policy Surprises

	Mean	Std. Dev.	Min.	Max.	Obs
Target Surprises (abs. values)	2.6	6.7	0.0	46.5	162
Target Surprises > 0	3.8	3.9	0.0	14.4	33
Target Surprises < 0	-6.2	11.0	-46.5	-0.3	47
Forward Guidance Surprises (abs. values)	6.0	6.5	0.0	54.6	162
Forward Guidance Surprises > 0	5.4	4.9	0.0	24.9	89
Forward Guidance Surprises < 0	-6.7	8.0	-54.6	-0.0	73
Asset Purchase Surprises (abs. values)	2.2	3.5	0.1	29.9	86
Asset Purchase Surprises > 0	1.9	2.2	0.1	10.3	41
Asset Purchase Surprises < 0	-2.5	4.4	-29.9	-0.1	45

Notes: This table reports the average, the standard deviation, the minimum and the maximum values on monetary policy announcement days for the target, forward guidance and asset purchase surprises, see section 1.5.2 for details. Target surprises are zero between January 2009 to November 2015. Forward guidance surprises span the whole sample period from January 2000 to January 2019. Asset purchase surprises are considered from October 2008 onwards.

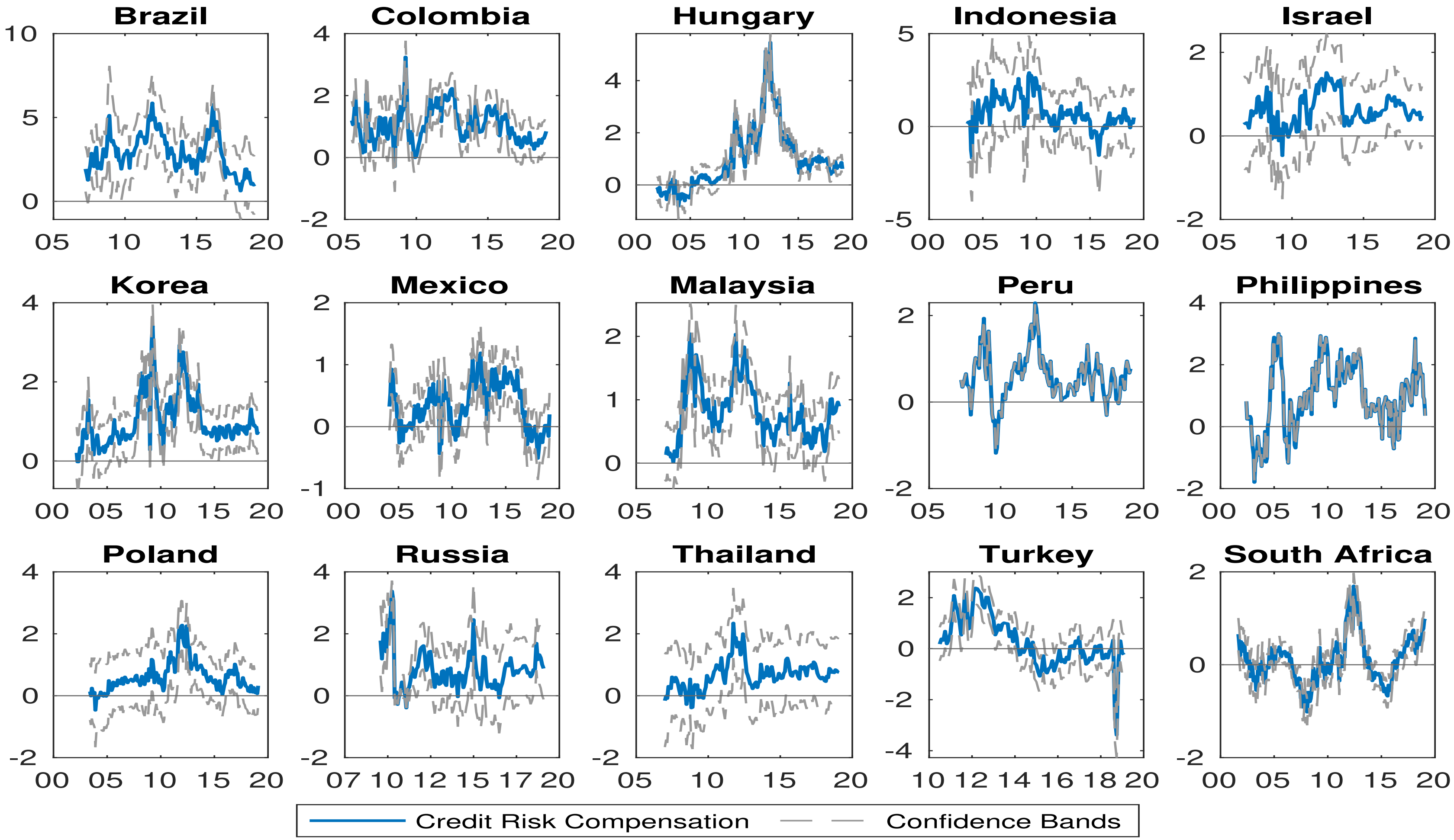
Appendix 1.D Supplementary Figures

Figure 1.D.1. The 10-Year Term Premium of Emerging Markets



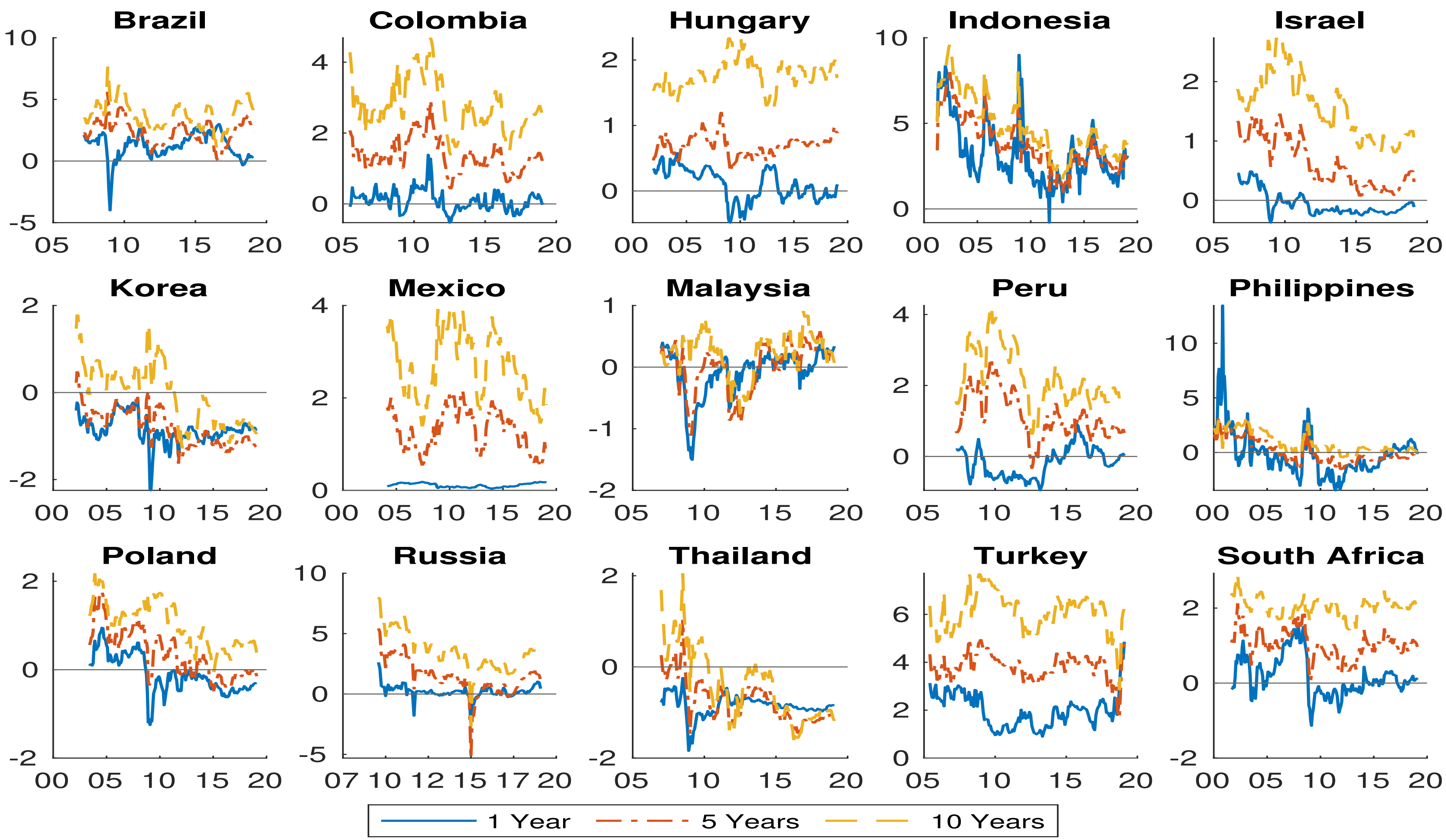
Notes: This figure plots the model-implied 10-year term premium (solid line) along with 2-standard-error confidence intervals (dashed lines). The standard errors are estimated using the delta method. The covariance matrix is estimated using the sample Hessian estimator calculated numerically from the joint log density.

Figure 1.D.2. The 10-Year Credit Risk Compensation of Emerging Markets



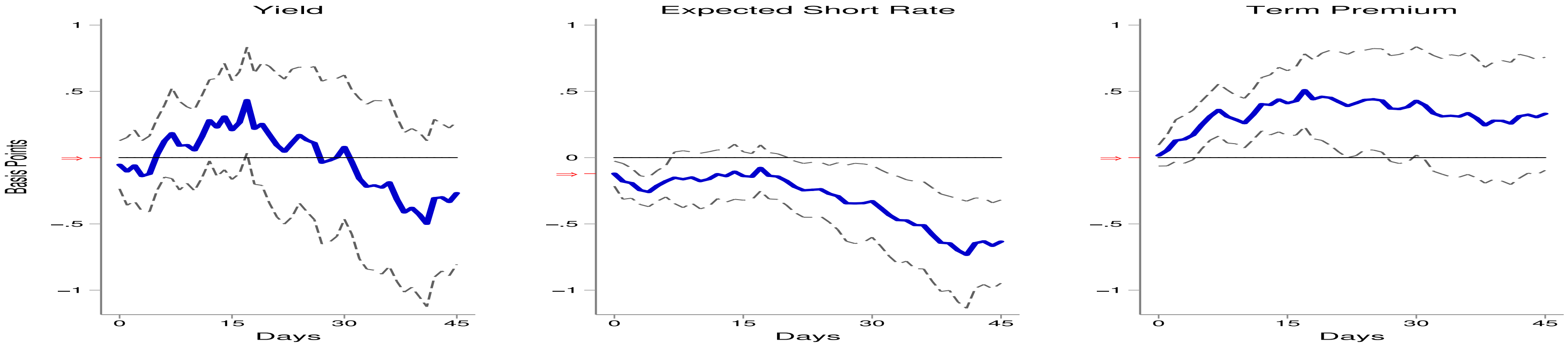
Notes: This figure plots the model-implied 10-year credit risk compensation (solid line) along with 2-standard-error confidence intervals (dashed lines). The standard errors are estimated using the delta method. The covariance matrix is estimated using the sample Hessian estimator calculated numerically from the joint log density.

Figure 1.D.3. Term Structure of Term Premia

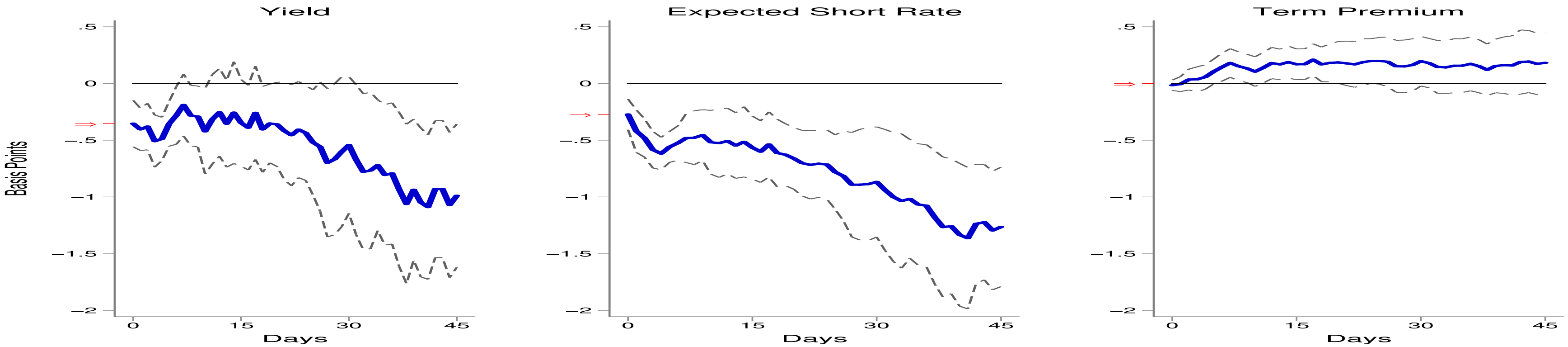


Notes: This figure plots the model-implied term premium for different maturities: 1 year (solid line), 5 years (dashed line) and 10 years (dash-dotted line).

Figure 1.D.4. Response of the U.S. Yield Curve to a Target Surprise



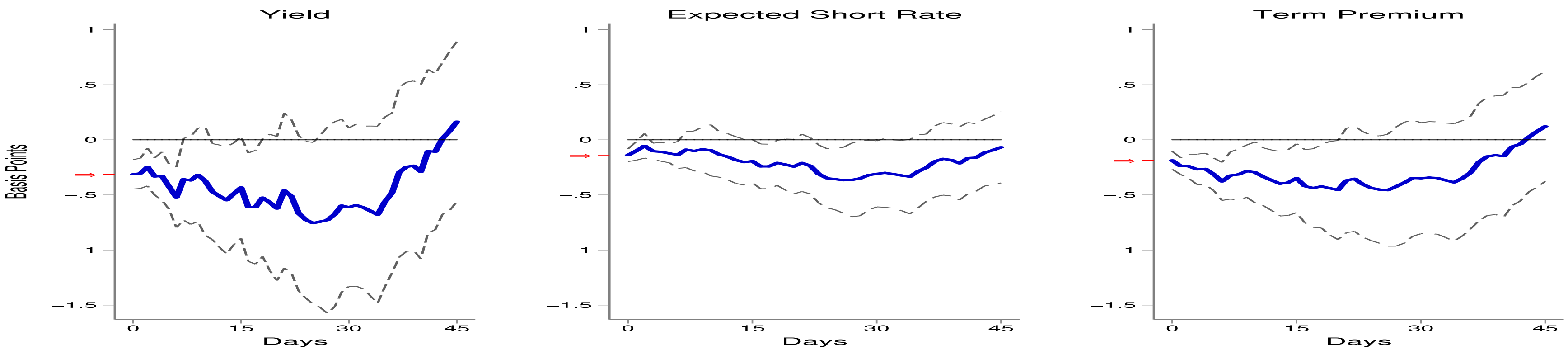
(a) 10-Year Yield



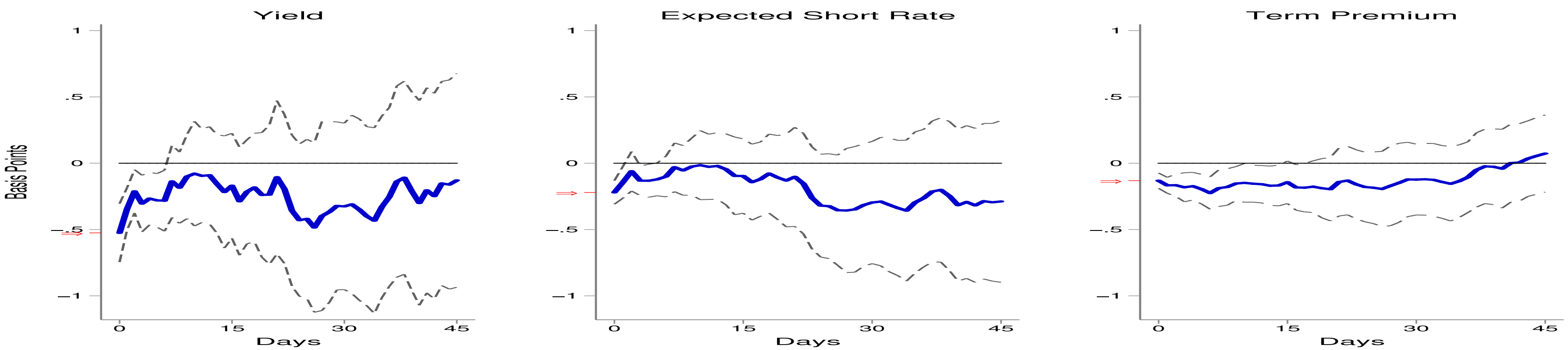
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year U.S. yields and their components to a target easing surprise of 1 basis point. U.S. yields are zero-coupon yields from Gürkaynak et al. (2007), and are decomposed into an expected future short-term interest rate and a term premium following Kim and Wright (2005). Target surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.D.5. Response of the U.S. Yield Curve to a Forward Guidance Surprise: 2000-2008



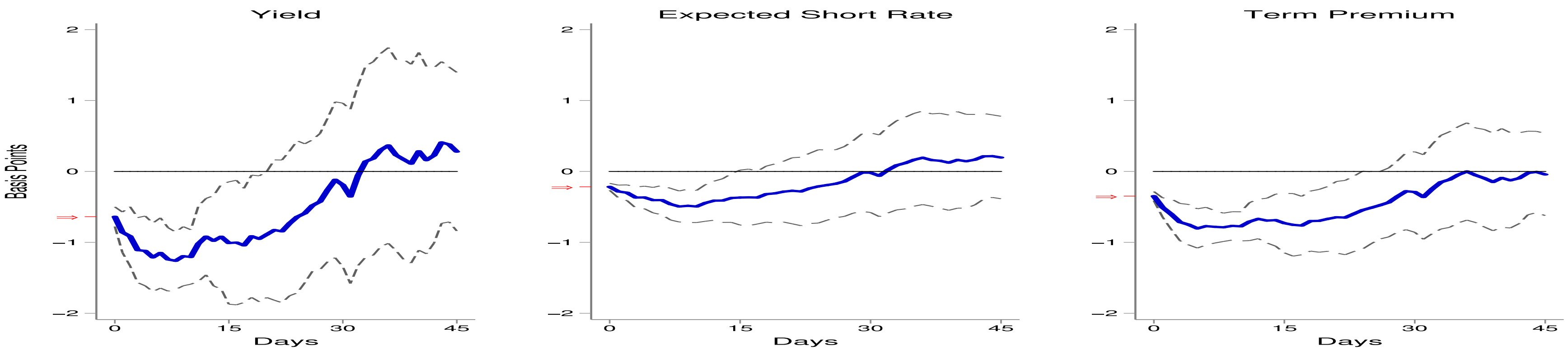
(a) 10-Year Yield



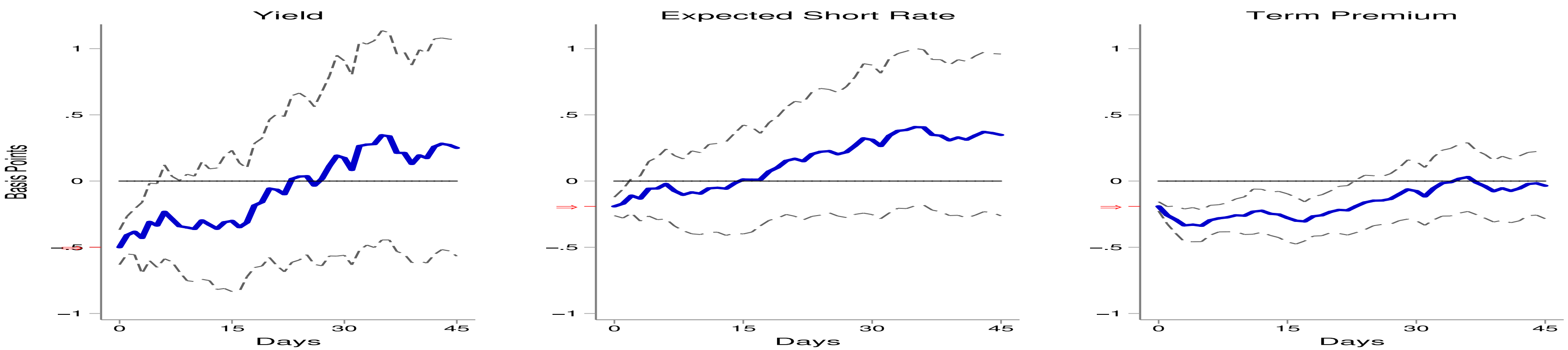
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year U.S. yields and their components to a forward guidance easing surprise of 1 basis point. U.S. yields are zero-coupon yields from Gürkaynak et al. (2007), and are decomposed into an expected future short-term interest rate and a term premium following Kim and Wright (2005). Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.D.6. Response of the U.S. Yield Curve to a Forward Guidance Surprise: 2008-2019



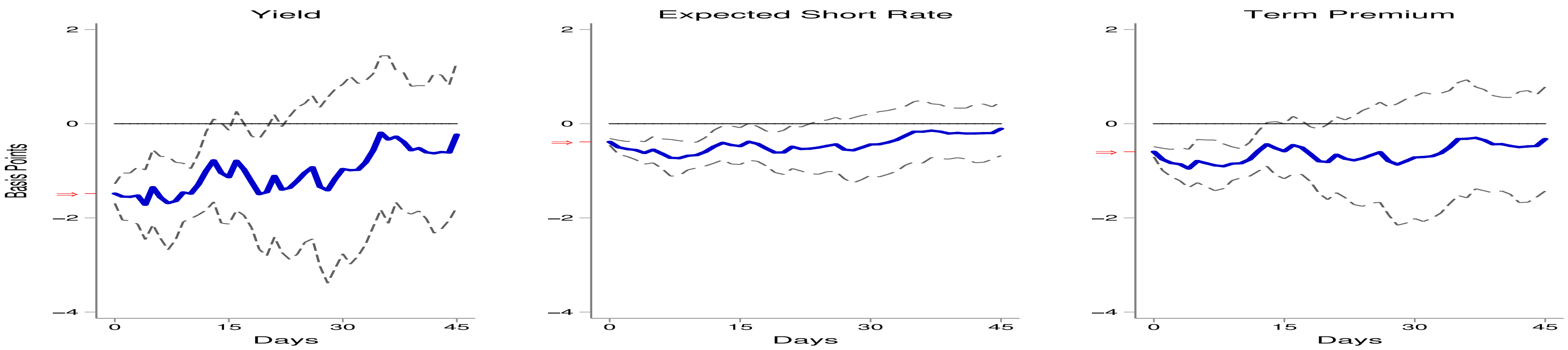
(a) 10-Year Yield



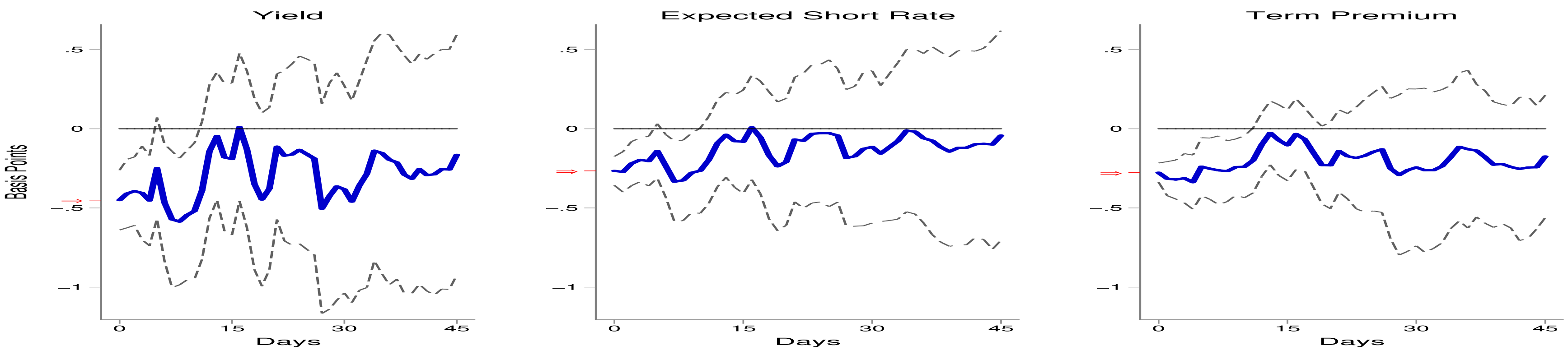
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year U.S. yields and their components to a forward guidance easing surprise of 1 basis point. U.S. yields are zero-coupon yields from Gürkaynak et al. (2007), and are decomposed into an expected future short-term interest rate and a term premium following Kim and Wright (2005). Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.D.7. Response of the U.S. Yield Curve to an Asset Purchase Surprise



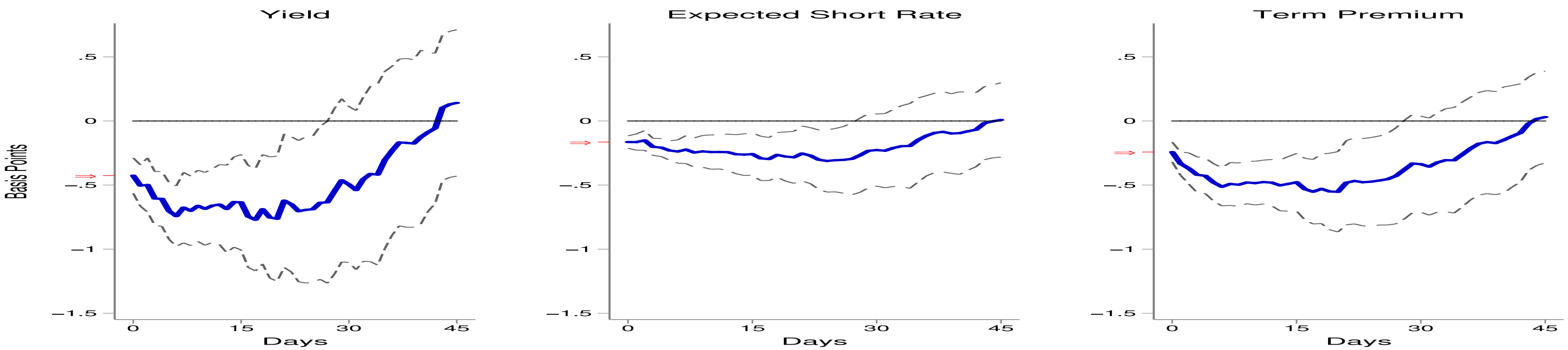
(a) 10-Year Yield



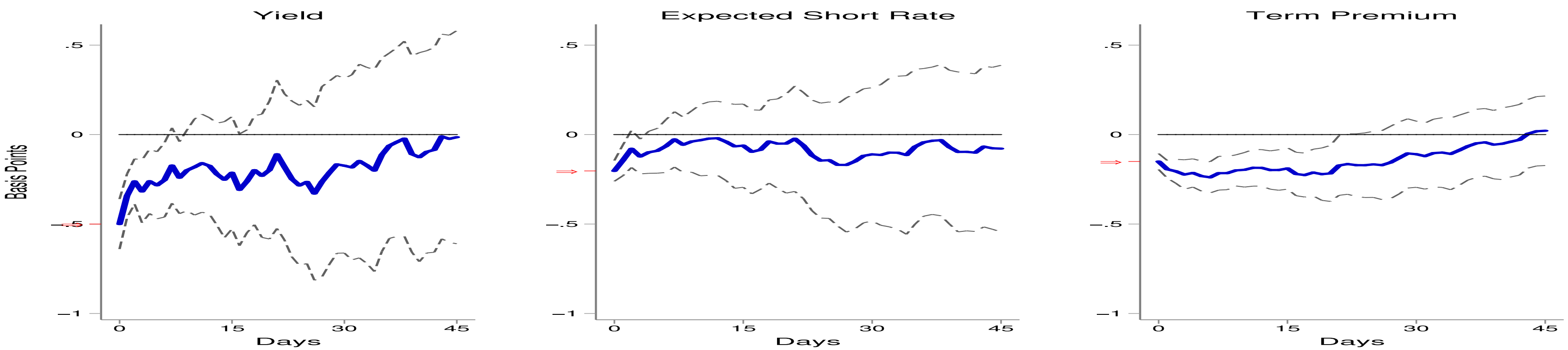
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year U.S. yields and their components to an asset purchase easing surprise of 1 basis point. U.S. yields are zero-coupon yields from Gürkaynak et al. (2007), and are decomposed into an expected future short-term interest rate and a term premium following Kim and Wright (2005). Asset purchase surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.D.8. Response of the U.S. Yield Curve to a Forward Guidance Surprise: 2000-2019



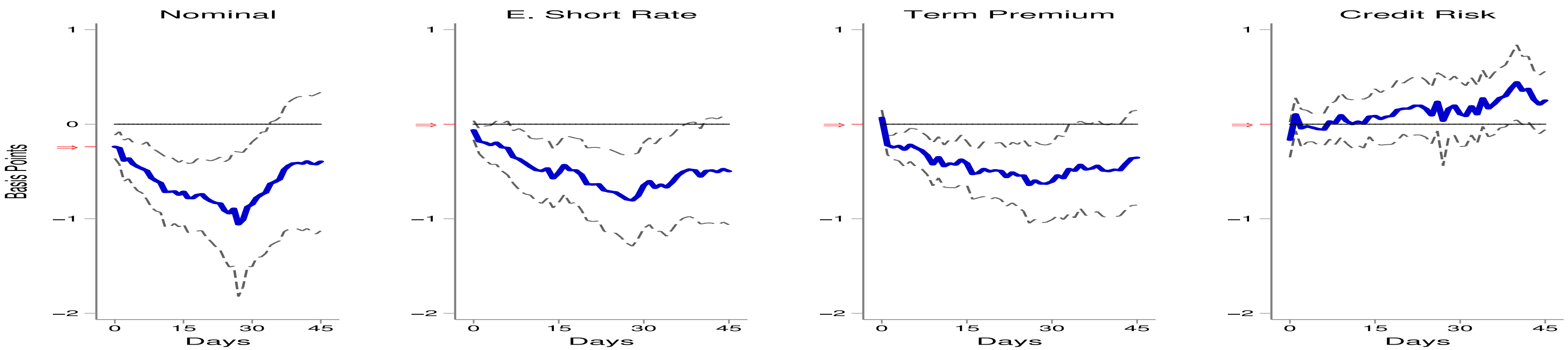
(a) 10-Year Yield



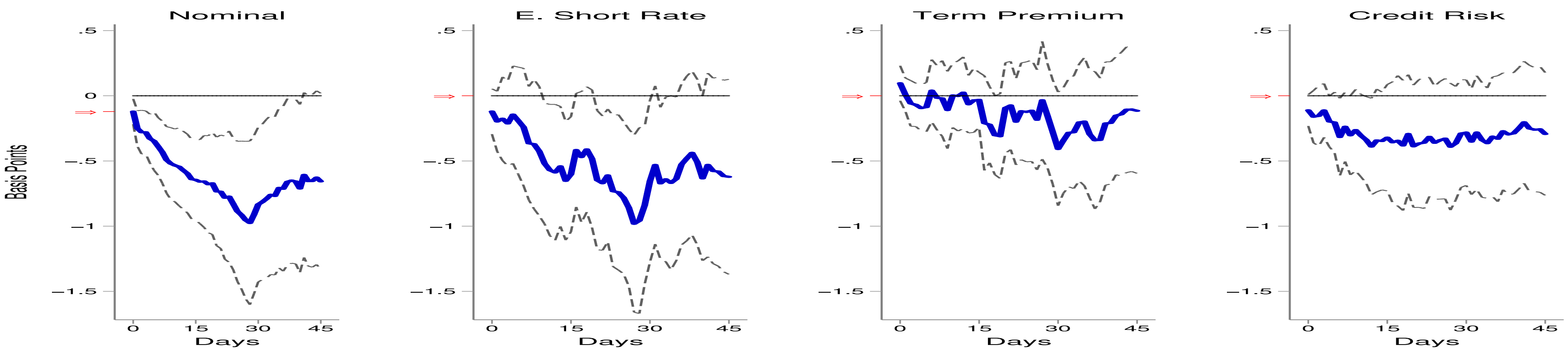
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year U.S. yields and their components to a forward guidance easing surprise of 1 basis point. U.S. yields are zero-coupon yields from Gürkaynak et al. (2007), and are decomposed into an expected future short-term interest rate and a term premium following Kim and Wright (2005). Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Figure 1.D.9. Response of Emerging Market Yield Curves to a Forward Guidance Surprise: 2000-2019



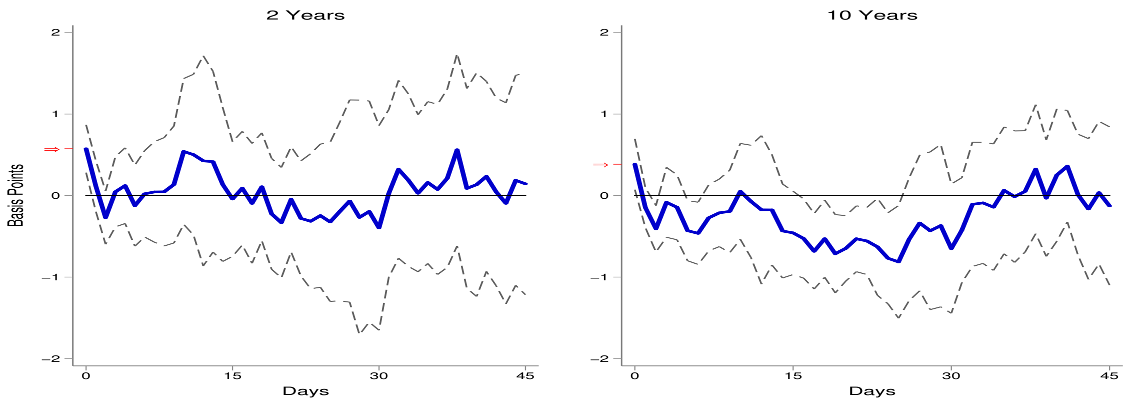
(a) 10-Year Yield



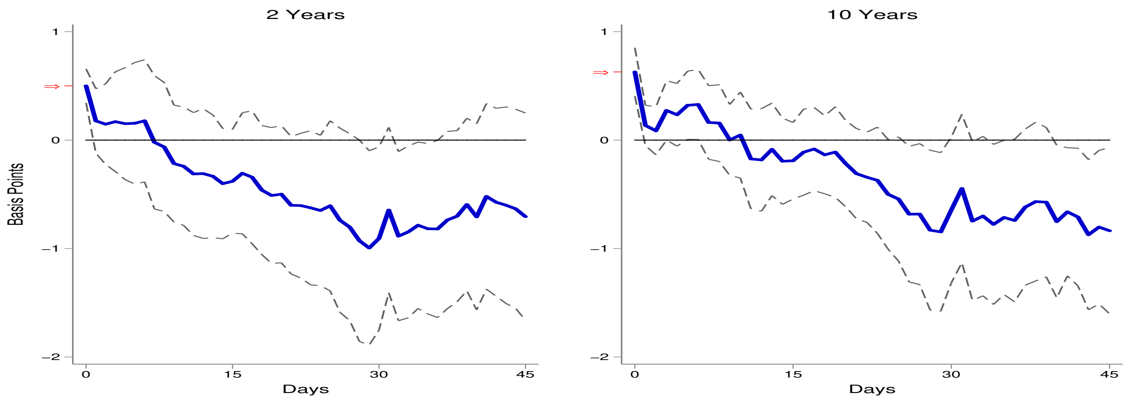
(b) 2-Year Yield

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year emerging market nominal yields and their components to a forward guidance easing surprise of 1 basis point. Nominal yields are decomposed into an expected future short-term interest rate, a term premium and credit risk compensation, see section 1.4 for details. Forward guidance surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

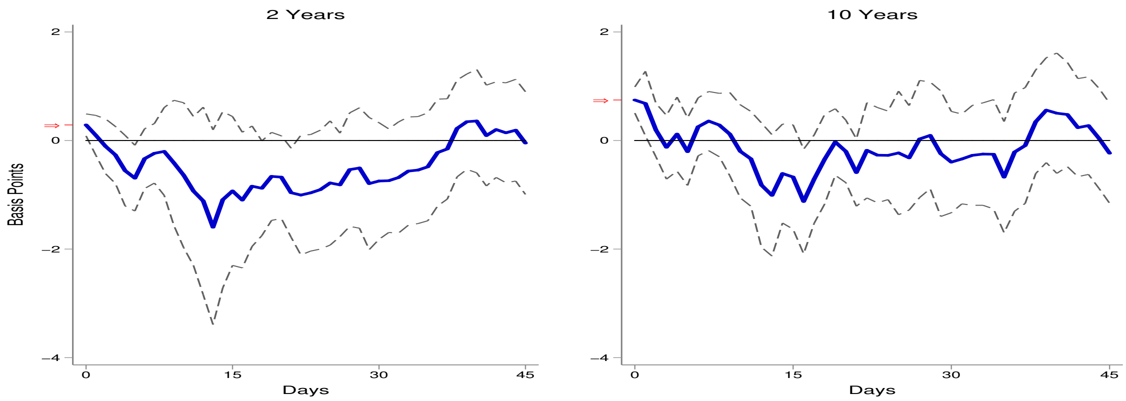
Figure 1.D.10. Response of the Forward Premium to U.S. Monetary Policy Surprises



(a) Target Surprise: 2000-2008



(b) Forward Guidance Surprise: 2000-2019



(c) Asset Purchase Surprise: 2009-2019

Notes: This figure shows the response following Jordà (2005) of the 10- and 2-year foreign exchange forward premium of emerging markets to easing surprises in U.S. monetary policy of 1 basis point. The forward premium is calculated using cross-currency swaps, which are in turn constructed using cross-currency basis swaps and interest rate swaps, see section 1.2.1 for details. The target, forward guidance and asset purchase surprises are identified using intraday data around Fed's monetary policy announcements, see section 1.5.2 for details. An arrow indicates the contemporaneous ($h = 0$) effect. The 90% confidence bands are based on Driscoll–Kraay standard errors.

Chapter 2

Does the Exchange Rate Respond to Monetary Policy in Emerging Markets? Evidence from Mexico

This paper quantifies the effects of monetary policy on the exchange rate and bond yields in Mexico and solves the 'high-frequency' exchange rate puzzle in emerging markets.

2.1 Introduction

The exchange rate response to monetary policy in emerging markets has so far been an unsolved puzzle. Standard open economy models suggest that an increase in the policy rate leads to an immediate appreciation of the currency (Dornbusch, 1976). Contrary to this prediction, earlier evidence for advanced economies (Grilli and Roubini, 1995), and recently for emerging markets (Kim and Lim, 2016), found that contractionary monetary policy leads to a currency depreciation, commonly referred to as the exchange rate puzzle. These results, however, can be attributed to the assumptions made to identify the monetary policy surprises (Zettelmeyer, 2004); for instance, monetary policy actions could in fact be reacting to changes in the exchange rate. Using more robust identification methods, subsequent studies for advanced economies report that a policy rate hike indeed leads to an appreciation of the currency (Kearns and Manners, 2006; Faust et al., 2007). Nevertheless, the same methods applied to emerging markets show that the currency response to monetary policy is low or nonexistent (Aktaş et al., 2009; Duran et al., 2012; Kohlscheen, 2014; Pennings et al., 2015), leading to a stronger version of the puzzle (Kohlscheen, 2014).

The exchange rate puzzle in emerging markets raises the question of whether their central banks can actually exert an influence on their own currencies. This question is particularly relevant for three reasons. First, the transmission of monetary policy via the exchange rate is vital for open economies. Second, the sensitivity of the currencies in advanced economies to monetary policy increased since the global financial crisis (Ferrari et al., 2017), even in countries who continued to use conventional tools—like Australia and Canada—and so it would be striking if emerging market currencies remained insensitive to monetary policy. Third, the currencies of emerging markets do respond to *foreign* monetary policy surprises (Hausman and Wongswan, 2011; Kearns et al., 2018).

This paper studies whether and how the exchange rate responds to monetary policy in a representative emerging economy, and compares the results with the response of the yield curve. This requires one to consider small open economies with relatively liquid financial assets, a market-based exchange rate, and a credible inflation targeting regime (Kearns and Manners, 2006; Pennings et al., 2015). Mexico meets all these criteria. I use an event study methodology and a new dataset of intraday and daily changes in asset prices bracketing monetary policy announcements in Mexico from 2011 to 2019. In particular, changes in swap rates are used to systematically measure surprises in the policy rate, independent of any model.[1] By now, event studies with high-frequency data are a well-established strategy in macro-finance to overcome endogeneity concerns because they isolate the surprise component of policy decisions (Gürkaynak and Wright, 2013; Nakamura and Steinsson, 2018).[2] Nevertheless, they have rarely been applied to study the monetary policy transmission to asset prices in Mexico.[3]

[1]The traditional approach to identify monetary policy surprises is to estimate a vector autoregression model using a recursive assumption, see Christiano et al. (1999). The exchange rate puzzle is a well-known feature of this approach, which Zettelmeyer (2004) attributes to a problem of reverse causality.

[2]It is reasonable to assume that surprises in monetary policy decisions on announcement days are exogenous and so one can give a causal interpretation from policy decisions to asset price responses.

[3]For the Mexican case, the event study methodology has been applied to analyze the effects of *foreign*

This paper documents significant responses of the exchange rate and the yield curve to policy rate surprises in Mexico. First, an unanticipated increase in the policy rate appreciates the currency; specifically, a 25 basis point increase in the rate leads to an appreciation of close to 50 basis points. This provides evidence against the exchange rate puzzle in emerging markets and thus shows that their currencies are no different to those in advanced economies in terms of their responsiveness to the domestic policy rate. Second, a contractionary monetary policy raises bond yields in a way that flattens the yield curve, also in line with the evidence for advanced economies. Moreover, policy rate surprises have a larger influence on the yield curve in Mexico than U.S. policy rate surprises have on the U.S. yield curve, potentially reflecting a relatively higher degree of long-term inflation uncertainty in Mexico.

The main contribution of the paper is to solve the exchange rate puzzle in emerging markets. Kohlscheen (2014) shows that the currencies of emerging markets do not respond to monetary policy using *daily* event studies and refers to it as the 'high-frequency' exchange rate puzzle. In contrast, the literature shows that the currencies of advanced economies react to monetary policy even using daily data, although the precision decreases relative to intraday data (Wright, 2012; Ferrari et al., 2017). I exploit the availability of two lengths for the event window (intraday and daily) in a validation study (Bound et al., 1994) to understand the puzzle.[4] The analysis reveals that the exchange rate response is sensitive to data frequency as it can only be perceived using intraday data. This sensitivity, however, is characteristic of the exchange rate since the effect of the policy rate on the yield curve can still be observed with daily data. The puzzle is thus the result of wide event windows when measuring the changes in the exchange rate, giving rise to a standard omitted variable bias. Intuitively, a lot of factors other than monetary policy decisions affect the exchange rate that even a daily frequency is not enough to prevent

monetary policy on asset prices (Borensztein et al., 2001; Rosa, 2011a; Hausman and Wongswan, 2011; Kearns et al., 2018) and portfolio flows (Hernandez Vega, 2018), whereas De Pooter et al. (2014) use it to study whether inflation expectations are well-anchored. The only exception is Kohlscheen (2014), who studies the exchange rate response to monetary policy as in this paper, but he does not use intraday data nor swaps to measure surprises in the policy rate.

[4]To the best of my knowledge, this is the first paper studying the effects of monetary policy in emerging markets that highlights the differences between intraday and daily changes in asset prices.

their influence. Using intraday data—at least for the exchange rate—avoids this problem.

An early interpretation of the exchange rate puzzle is that some countries—particularly emerging markets—have a preference for smooth currency fluctuations or, equivalently, that they fear large currency swings (Calvo and Reinhart, 2002). This 'fear of floating' would make the central bank adjust its policies—including changes in the policy rate and foreign exchange interventions—so as to keep the currency from experiencing large swings. This, however, is unrelated to the question of whether an unanticipated change in the policy rate affects the currency. In fact, by focusing on the effects of policy rate surprises, this paper is neutral on how monetary policy expectations are determined.

The paper proceeds as follows. Section 3.2 describes how policy rate surprises are measured, and section 2.3 discusses their effects on the exchange rate and the yield curve. Section 2.4 addresses the high-frequency exchange rate puzzle. The last section concludes.

2.2 Identification of Policy Rate Surprises

This section briefly reviews the institutional developments in Mexico that are relevant for the identification of policy rate surprises. It then describes how to measure them.

2.2.1 Monetary Policy in Mexico

The Bank of Mexico, also known as Banxico, is an independent central bank that implements monetary policy through a five-member Governing Board. The governor of Banxico is the chair of the Board, the other four members are deputy governors.

Analyses of the policy rate with daily data can arguably start in 2004 based on the following. When Banxico was granted autonomy in 1994, inflation was 7%. Less than a year later, the Mexican peso crisis started (in December 1994). As a result, inflation peaked at 52% and a floating exchange rate system was adopted (Carstens and Werner, 1999). During 1999, inflation decreased from 19 to 12%, and Banxico announced that inflation should decrease to 3% by the end of 2003. In line with this goal, inflation targeting was formally adopted in 2001 and one year later, the official target for inflation was set at 3% with respective upper and lower bounds of 4 and 2%. Since 2003, Banxico follows a calendar of monetary policy meetings which is publicly announced ahead of time. The transition period for the adoption of Banxico's current monetary policy instrument, the overnight interbank interest rate, started in 2004 and concluded in 2008.[5]

After the adoption of the overnight policy rate, two major institutional changes were made. First, although monetary policy statements have accompanied every policy decision since 2000, Banxico started releasing minutes of its monetary policy meetings two weeks after the date of the respective policy decision in 2011. Second, the timing of the announcements was modified in 2015. Up until 2014, the announcements were made at 9 a.m. local time on the scheduled day, usually Fridays. Since 2015, announcements are now made at 1 p.m. local time on the scheduled day, usually Thursdays.[6]

The regularity and scheduled timing of these announcements allow me to study the effects of policy decisions on asset prices using an event study methodology. Appendix 2.A contains a list of the dates and times of Banxico's monetary policy announcements since 2004, along with relevant macroeconomic data from Mexico and the U.S. released on the same days. From 2004 to 2019, there were 155 regularly scheduled monetary policy announcements, and 72 between 2011 and 2019.[7] On average, Banxico's Governing Board met monthly between 2004 and 2010, and every six weeks since 2011.

Figure 2.1 shows the evolution of the policy rate along with the *changes* in the rate since it was adopted. After the global financial crisis intensified, Banxico cut its policy rate by 3.75% in 7 months. More stimulus started in March 2013 via an unanticipated 50 basis point reduction in the rate.[8] Since then, the first increase in the rate occurred in December 2015, a day after the first hike in the U.S. policy rate since the Great Recession. The tightening cycle intensified in the second half of 2016 due to inflation concerns linked

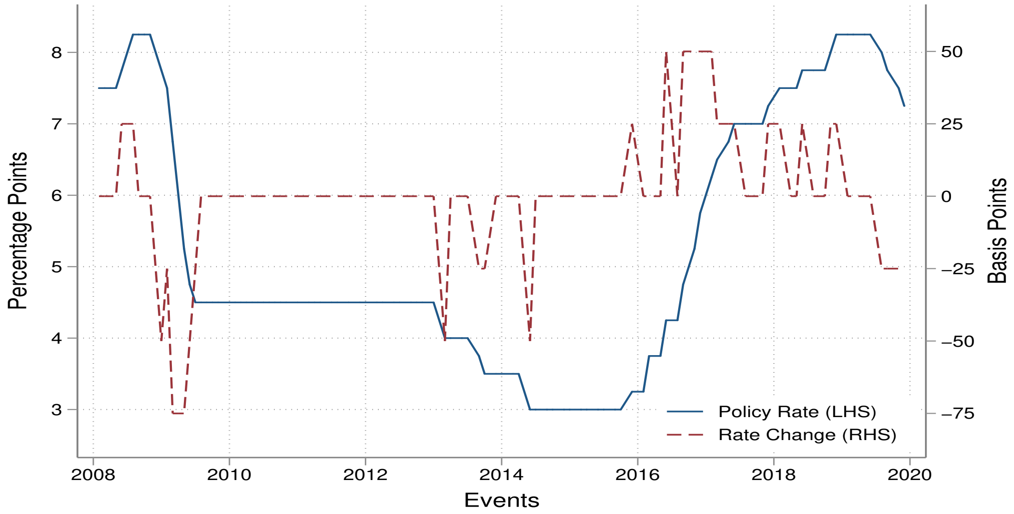
[5]Before 2008, Banxico used a quantitative target, 'el corto', which indirectly influenced interest rates. Sidaoui and Ramos-Francia (2008) review the transmission of monetary policy in Mexico since the 1994-95 currency crisis until the adoption of the current policy rate.

[6]According to Banxico's governor at the time, the new timing gives market participants more time to react to policy decisions before the weekend.

[7]Appendix 2.B explains the reasons for excluding an extraordinary meeting on February 2016.

[8]A basis point is equal to one hundredth of one percent.

Figure 2.1. Policy Rate in Mexico: Level and Change



Notes: This figure shows the evolution of the level (solid line) and the raw change (dashed line) of the overnight interbank interest rate, the policy rate in Mexico, from January 2008 to December 2019.

to a deprecation of the currency and the 2016 U.S. presidential election.

Timing of the Announcements

To correctly measure intraday policy rate surprises, it is crucial to have the *time* of the announcements right. In particular, one needs to consider both the change in the timing of Banxico's announcements of 2015 and the usage of Daylight Saving Time (DST).

Due to the 2015 change in the timing of Banxico's policy announcements, there are two relevant times: 9 a.m. up until 2014 and 1 p.m. afterwards, both expressed in the Central Time zone used in Mexico's capital. The data, however, is recorded in the Eastern Time (ET) zone used in the U.S. capital. The time zone matters because the usual one-hour time difference between the two cities widens to two hours during non-overlapping DST days since 2007, when the U.S. extended its usage of DST time unlike Mexico. The relevant ET times for Banxico's policy decisions are then as follows. All announcements before 2007 happened at 10 a.m. ET. Between 2007 and 2014, the announcements occurred at 10 a.m. ET most of the time, except on non-overlapping

DST days in which they occurred at 11 a.m. ET. Finally, since 2015 the announcements take place at 2 p.m. ET most of the time, except on non-overlapping DST days in which they occurred at 3 p.m. ET. Further details are in appendix 2.A.

2.2.2 Measuring Policy Rate Surprises

It is important to focus on 'surprises' in policy decisions. The raw change in the policy rate can be decomposed into an expected and an unexpected part. Kuttner (2001) shows that asset prices only respond to unexpected changes, since the expected part is already reflected in prices by the time of the announcement. The unanticipated part is thus the relevant component of policy decisions, usually referred to as the 'surprise' or the 'shock'.[9]

One can think of policy rate surprises as the difference between the raw change in the policy rate and the expected one. Surveys of professional forecasters are one source of expectations about monetary policy decisions. Alternatively, financial market prices can be used to obtain a market-based measure of those expectations.[10]

This paper uses swap rates to measure surprises in the policy rate. An overnight indexed swap (OIS) referencing the policy rate would be an ideal candidate.[11] Instead, the swap market in Mexico references an interbank interest rate denominated in local currency that closely follows the policy rate, the 28-day interbank interest rate (TIIE28D).[12] Banxico calculates the TIIE28D once a day based on quotes it receives from commercial banks, it is the benchmark rate for banking loans in Mexico. The most liquid swap with the shortest maturity and the longest history is the 3-month swap; it is indeed the main local derivative.[13] Importantly, unlike the TIIE28D itself, the 3-month swap trades within the day, which allows me to calculate differences in the swap rate in intraday windows.[14] Even though the 3-month swap might capture more than one policy meeting ahead, it is still a good measure of the monetary stance in the short run.

[9] Leaving the policy rate unchanged can still be a surprise if market participants expected a move. For instance, a zero raw change can be a loosening surprise if the market expected a 25 basis point increase.

[10] Kuttner (2001), for instance, uses futures on the federal funds rate for the U.S.

[11] As an alternative to the U.S.-specific futures contracts of the policy rate, Lloyd (2018) shows that OIS can be used to measure monetary policy surprises in Germany, Japan, the U.S. and the U.K.

[12] The average difference between the TIIE28D and the overnight policy rate is around 30 basis points.

[13] Currently, a 1-month swap is also traded in the market but is not as liquid and has a shorter history.

[14] Appendix 2.C discusses relevant considerations if TIIE28D were to be used to measure the surprises.

Policy rate surprises are equal to the difference in swap rates around windows containing monetary policy announcements. The difference is model-free and represent a change in the information set of market participants, the surprise. A positive surprise refers to a tightening of the monetary stance, while a negative value represents an easing.

The difference in swap rates captures the change in expectations for the policy rate around the announcements. Even though swap rates can be decomposed into an expectation for the policy rate and a risk premium,[15] the premium is not a problem to how the surprises are measured as long as it does not change over the length of the window, a reasonable assumption given that risk premia vary at business-cycle frequencies (Piazzesi and Swanson, 2008; García-Verdú et al., 2019).[16] In fact, Piazzesi and Swanson (2008) document that monetary policy surprises based on the *change* in the derivatives rate over small windows around the announcements are robust to the presence of risk premia. Moreover, García-Verdú et al. (2019) show that the risk premium in TIIE28D swap rates is relevant at medium but not at short horizons—the 3-month swap in particular.

A Dataset of Asset Price Changes

The preferred measure of policy rate surprises in this paper is the difference in the 3-month swap rate in 30-minute windows bracketing monetary policy announcements.[17] The windows start 10 minutes before and end 20 minutes after each monetary policy announcement.[18] Similarly, differences over the same intraday windows are also calculated for the exchange rate (expressed in pesos per U.S. dollar) and for yields of bonds issued by the Mexican government with maturities of 2, 5, 10 and 30 years.[19]

Given that access to intraday data in emerging markets is not as common as for advanced economies, daily changes for all the assets are also used, calculated as the one-

[15] A risk premium compensates investors in case their policy rate expectations turned out to be wrong.

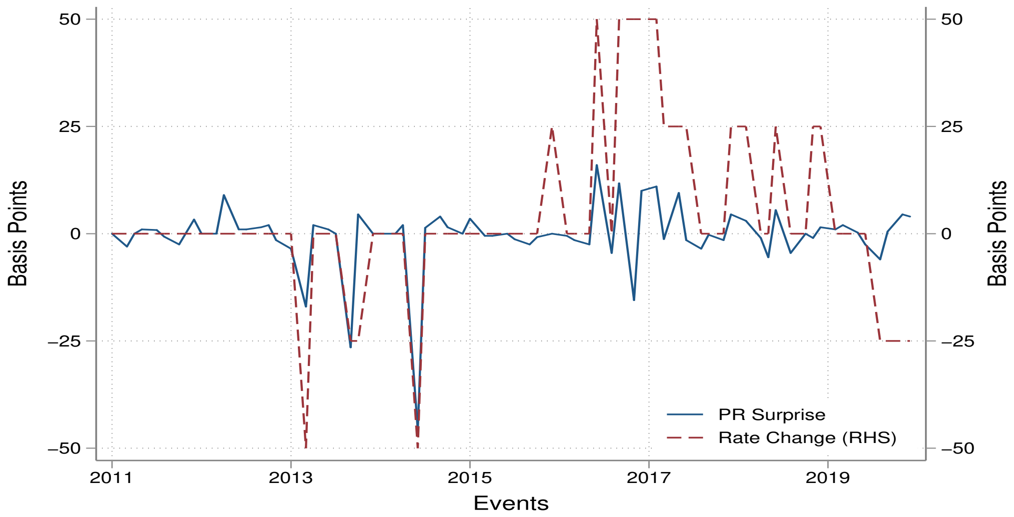
[16] Also notice that the change in the swap rate differences out any constant risk premium.

[17] An alternative measure, used by De Pooter et al. (2014), is the difference between the actual policy rate change and the average of survey expectations. The correlation between the two measures is 0.92.

[18] Wider 50-minute windows, starting 20 minutes before and ending 30 minutes after each announcement, were used in robustness checks. All the results with tight windows hold using wider windows.

[19] When no data is available at any of those times, the next available quote is used to compute the changes. In extreme cases, in which there are no quotes in wider windows for a day, the open and close quotes are used to compute the change in the rates. This only happens for the swaps on a few days.

Figure 2.2. Policy Rate in Mexico: Surprises and Change



Notes: This figure shows the evolution of the policy rate surprises (solid line) and the raw change in the policy rate (dashed line). Policy rate surprises are equal to the change in the 3-month swap rate in 30-minute windows bracketing monetary policy announcements. The events are all regular monetary policy announcements from January 2011 to December 2019.

day change in the price around monetary policy announcements. The comparison of the results using intraday versus daily data receives special attention in the rest of the paper, playing a key role in section 2.4 on the high-frequency exchange rate puzzle.

All the data for the analysis comes from Bloomberg. The information to calculate the intraday change for the swap rates and the exchange rate is available since 2011, since December 2014 for the 5-year yield and since 2013 for the other yields. Daily changes start in 2004, except for the 30-year yield for which they start in October 2006.

Figure 2.2 plots the raw changes in the policy rate along with the (intraday) policy rate surprises. The difference between the two is the anticipated change in the policy rate. Notice that surprises are generally smaller than the raw changes, indicating that most of the policy rate decisions of Banxico are anticipated by market participants.

Table 2.1 shows summary statistics for the intraday and daily changes in asset prices. According to the policy rate surprises identified using intraday data, there was no surprise in 12 out of the 72 regularly scheduled meetings between 2011 and 2019. Moreover, several of the insights documented formally in the next two sections can already be seen in

Table 2.1. Summary Statistics for Asset Price Changes

	Mean	Std. Dev.	Min.	Max.	Obs.
Intraday					
PRS	-0.5	7.9	-45.8	16.0	72
PRS > 0	4.0	4.0	0.3	16.0	31
PRS < 0	-5.5	9.7	-45.8	-0.3	29
FX	-9.4	33.4	-165.4	55.3	72
2Y Yield	-0.4	6.7	-37.7	10.7	56
5Y Yield	-0.0	3.9	-15.4	9.4	41
10Y Yield	-0.6	5.0	-25.8	10.9	56
30Y Yield	-0.8	4.4	-19.8	8.2	56
Daily					
PRS	-0.5	8.1	-45.8	16.0	72
PRS > 0	4.3	4.6	0.2	16.0	30
PRS < 0	-5.3	9.5	-45.8	-0.2	31
FX	-7.0	65.4	-167.6	142.2	72
2Y Yield	-1.2	7.6	-32.6	13.3	72
5Y Yield	-1.8	8.5	-41.1	12.9	72
10Y Yield	-1.8	7.7	-34.8	10.4	72
30Y Yield	-2.0	7.0	-28.1	12.6	72

Notes: This table reports summary statistics for intraday and daily changes in the 3-month swap rate (the policy rate surprises or PRS), changes in bond yields and exchange rate returns (FX). Intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. Figures in decimals are expressed in basis points. The sample period is from January 2011 to December 2019.

table 2.1. There is no much difference between the policy rate surprises calculated using intraday and daily data. Changes in bond yields using the two frequencies also have similar characteristics, although they vary slightly more using daily data. In contrast, the standard deviation of the exchange rate returns almost doubles (from 33 to 65 basis points) when the frequency goes from intraday to daily.

2.3 The Effects of Policy Rate Surprises on Asset Prices

This section documents that the response of asset prices to policy rate surprises is statistically and economically significant. It also shows that the comparison of the results from intraday and daily data turns out to be relevant for the exchange rate.

2.3.1 Methodology

The analysis of the response of the exchange rate and bond yields to policy rate surprises uses the following event-study regression:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \varepsilon_t, \tag{2.1}$$

in which Δy_t is the change in the variable of interest (exchange rate or bond yields) and Δx_t is the policy rate surprise (i.e. the change in the 3-month swap rate), both computed over the same window around monetary policy announcements. Whenever interest rates are used, the changes are calculated directly using quotes before and after the announcements; for the exchange rate, 100 times log differences are used to approximate the percentage change (or return) over the window. All variables are expressed in basis points. Finally, the error term ε_t captures variations in the dependent variable unrelated to shocks in the policy rate.

The parameter of interest in equation (2.1) is the slope coefficient β_1, it measures the response of asset prices to policy rate surprises.[20] The classical assumption to identify β_1 is that ε_t is orthogonal to Δx_t, which is equivalent to say that Δx_t is exogenous.

The frequency at which asset price changes are calculated is crucial to satisfy the exogeneity assumption. When Δx_t is measured as the intraday change in the 3-month swap rate around monetary policy announcements—conceptually the policy rate surprise—the exogeneity assumption is plausible. It is unlikely that, during such small windows, other variables influence asset prices in a systematic fashion or that monetary policy reacts to events happening minutes before the announcements are released. One can then give a causal interpretation from policy decisions to asset price responses on the days of monetary policy announcements (Gürkaynak and Wright, 2013).

The variable of interest starts to be measured with 'noise' when wider windows are used to calculate the changes in asset prices. The wider the window, the larger the noise.

[20]The intercept β_0 is generally dropped because the asset price is not expected to change when there is no surprise in the policy rate in small windows.

Such noise, or measurement error, opens the door for other variables to play a role in the relationship between asset prices and policy rate surprises. For example, since asset prices and the policy rate are both forward-looking variables, the estimation of equation (2.1) using quarterly or monthly data is plagued with endogeneity problems (e.g. simultaneity, omitted variables). Daily data mitigates those problems. Nevertheless, even with daily data, the noise can blur the relationship between the variables of interest in certain situations, as is discussed in section 2.4.

2.3.2 Results

The sign of β_1 depends on the dependent variable. Regarding the exchange rate, uncovered interest rate parity implies that the interest rate differential between Mexico and the U.S. should equal the expected change in the exchange rate. Other things equal, an increase in the interest rate in Mexico should lead to a contemporaneous appreciation of the peso, i.e. a fall in the exchange rate.[21] Thus, β_1 is expected to be negative for the exchange rate. Regarding bond yields, Kuttner (2001) shows that a monetary tightening leads to higher yields at all maturities due to upward expectations for the policy rate. As such, β_1 is expected to be positive for the yield curve.

Intraday Data

Table 2.2 presents the results of estimating equation (2.1) using intraday data. The first column for each of the dependent variables reports the estimate of β_1. In all cases, the estimates have the expected sign and are highly significant.

A 25 basis point increase in the policy rate leads to an appreciation of the currency of close to 50 basis points. For comparison, the currencies of advanced economies responded around two times the magnitude of the policy rate surprise before the global financial crisis (Rosa, 2011b) and up to five times afterwards (Wright, 2012; Ferrari et al., 2017). Table 2.2 thus provides evidence against the exchange rate puzzle in emerging markets,

[21] Uncovered interest rate parity also implies that a contemporaneous appreciation of the peso generates an expected depreciation over time that offsets the initial increase in the interest rate in Mexico.

Table 2.2. The Response of Asset Prices to Policy Rate Surprises: Intraday Data

	FX		2Y-Yield		5Y-Yield		10Y-Yield		30Y-Yield	
PR Surprise	-1.85**	-1.79**	0.67***	0.68***	0.34***	0.37***	0.42***	0.43***	0.30***	0.32***
	(0.89)	(0.85)	(0.09)	(0.08)	(0.11)	(0.09)	(0.09)	(0.09)	(0.08)	(0.07)
PR Expected		-0.20		-0.04		-0.04*		-0.05		-0.06**
		(0.34)		(0.03)		(0.02)		(0.04)		(0.03)
Observations	72	72	56	56	41	41	56	56	56	56
R-squared	0.18	0.19	0.79	0.81	0.23	0.27	0.53	0.56	0.35	0.42

Notes: The first column for each dependent variable shows the coefficient estimates in regressions of intraday yield changes or exchange rate returns (FX) on intraday changes in the 3-month swap rate (PR Surprise). The second column adds the expected component of the raw change in the policy rate (PR Expected) as a regressor, calculated as the difference between the raw change and the policy rate surprise. Intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. The events are all regular monetary policy announcements from January 2011 to December 2019. The sample for the exchange rate is from January 2011 to December 2019; for 2- 10- and 30-year yields, from January 2013 to December 2019; and for 5-year yields, from December 2014 to December 2019. Figures are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

it shows that their currencies are no different to those in advanced economies in terms of their responsiveness to the policy rate.

A contractionary monetary policy also flattens the yield curve. Following a 25 basis point hike in the policy rate, 2- 5- 10- and 30-year bond yields increase by approximately 17, 9, 11, and 8 basis points, respectively; as such, the spread between the 10- and 2-year yields—the term spread—narrows by 6 basis points.[22] These results are in line with the evidence for the U.S. in a comparable period, i.e. when its policy rate was not constrained by the effective lower bound (Kuttner, 2001; Gürkaynak et al., 2005). However, it is worth pointing out two differences. First, the magnitude of the yields' response in Mexico is larger than in the U.S. For instance, a 1/4 percentage point increase in the policy rate raises 2- 5- and 10-year yields by approximately 11, 7 and 3 basis points in the U.S. according to the estimates in Gürkaynak et al. (2005). Second, policy rate surprises in Mexico explain a larger fraction of the variability in bond yields (measured by the R^2 statistic) than in the U.S. Specifically, the surprises are the most important factor influencing 2- and 10-year yields in Mexico, with an R^2 of 0.79 and 0.53 versus 0.4 and 0.08 in the U.S., respectively.

The larger influence of policy rate surprises on the yield curve in Mexico compared to the U.S. likely reflects a relatively higher degree of long-term inflation uncertainty in Mexico. Bond yields can be decomposed into an average expected future short rate and a risk premium, which are partly driven respectively by expected inflation and inflation uncertainty (Abrahams et al., 2016)—together referred to as inflation compensation. De Pooter et al. (2014) argue that inflation expectations in Mexico have become anchored since Banxico adopted an inflation targeting regime. Nonetheless, in their Table 9 they show that surprises in the policy rate can sometimes influence long-term inflation compensation, which suggests that inflation expectations in Mexico are less firmly anchored than in the U.S. With relatively higher long-term inflation uncertainty, the effect of policy rate surprises on long-term yields will be bigger in Mexico relative to the U.S.[23]

[22]The effect on bond yields seems to be non-monotonic since the response of the 5-year yield is lower than for the 2- and 10-year yields. Nonetheless, this is less pronounced with daily data (see table 2.3).

[23]Solís (2021b) shows that inflation uncertainty is an important driver for the long-term yields of emerging markets.

The second column for each dependent variable in table 2.2 reports the responses of asset prices to the two components of the raw changes in the policy rate, the anticipated and unanticipated parts.[24] Similar to the findings in Kuttner (2001) for the U.S., asset prices in Mexico respond to surprises but not to anticipated changes in the policy rate.[25] This highlights the importance of focusing on policy rate surprises in emerging markets as well. Indeed, if raw changes were being used instead, one would incorrectly conclude that monetary policy has no effect on neither the currency nor the yield curve.[26]

Summing up, there is a statistically and economically significant response of the exchange rate and the yield curve to policy rate *surprises*.

Daily Data

Table 2.3 reports the results of estimating equation (2.1) using daily, instead of intraday, data. Remember that although intraday changes in swap rates and the exchange rate are available since 2011 (and somewhat later for bond yields), daily data is available much earlier for all assets. Thus, the first column for each dependent variable in table 2.3 reports the results over the same sample period as in table 2.2, while the second column shows the results since 2004.

The first column of table 2.3 illustrates the exchange rate puzzle identified by Kohlscheen (2014); that is, the exchange rate does not respond to policy rate surprises when the changes are calculated using daily windows. This is discussed in detail in section 2.4.

Unlike the exchange rate, the significance of the effects on the yield curve remains high. The results are broadly similar even with a larger sample size.[27] In addition, there are gains in the precision of the coefficient estimates and in terms of explanatory power (measured by R^2) when going from daily to intraday data. The largest gains, however, can be seen in the long end of the curve, where the standard error is half as large and

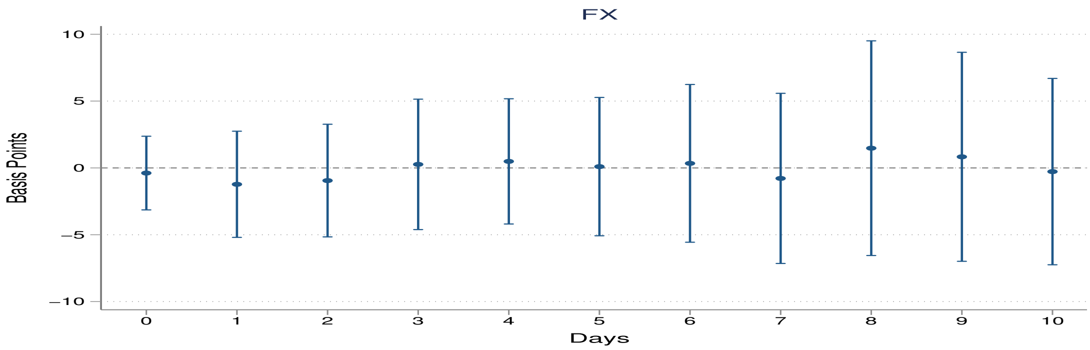
[24]The expected part equals the difference between the raw change and the surprise in the policy rate.
[25]The statistically significant effects of the anticipated part are economically small.
[26]In unreported regressions of intraday asset price changes on raw changes in the policy rate, the slope coefficient is not significant. These regressions suffer from an error-in-variables problem because the raw change is a noisy measure of the surprise component, which leads to attenuation bias (Kuttner, 2001).
[27]The differences amount up to 4 basis points under a 25 basis point change in the policy rate.

Table 2.3. The Response of Asset Prices to Policy Rate Surprises: Daily Data

	FX		2Y-Yield		5Y-Yield		10Y-Yield		30Y-Yield	
PR Surprise	-0.08	0.08	0.65***	0.48***	0.47***	0.50***	0.55***	0.44***	0.35**	0.39***
	(1.34)	(0.52)	(0.09)	(0.07)	(0.15)	(0.09)	(0.14)	(0.08)	(0.17)	(0.09)
Obs. since 2011	72		56		41		56		56	
Obs. since 2004		155		155		155		155		120
R-squared	0.00	0.00	0.55	0.41	0.19	0.35	0.42	0.25	0.18	0.22

Notes: This table shows the coefficient estimates in regressions of daily yield changes or exchange rate returns (FX) on daily changes in the 3-month swap rate (PR Surprise). Daily changes are calculated around monetary policy announcements. The first column for each dependent variable uses the same sample period as Table 2.2: for the exchange rate from January 2011 to December 2019, for 2- 10- and 30-year yields from January 2013 to December 2019, and for 5-year yields from December 2014 to December 2019. The second column uses a larger sample period, it includes all regular monetary policy announcements from January 2004 to December 2019. Figures are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Figure 2.3. Persistence of the Exchange Rate Response to Policy Rate Surprises



Notes: This figure plots the coefficient estimates and 95% confidence intervals for the response of the exchange rate return to policy rate surprises. Returns are calculated from close of day $t-1$ to day $t+k$, where t is a day with a monetary policy announcement and $k = 0, 1, \ldots, 10$. The announcements are always more than ten days apart from each other, see appendix 2.A. The sample includes all regular monetary policy announcements from January 2011 to December 2019.

the R^2 almost doubles when intraday data is used.

The main conclusion from comparing tables 2.2 and 2.3 is that intraday data is key to identify the currency response to the policy rate.

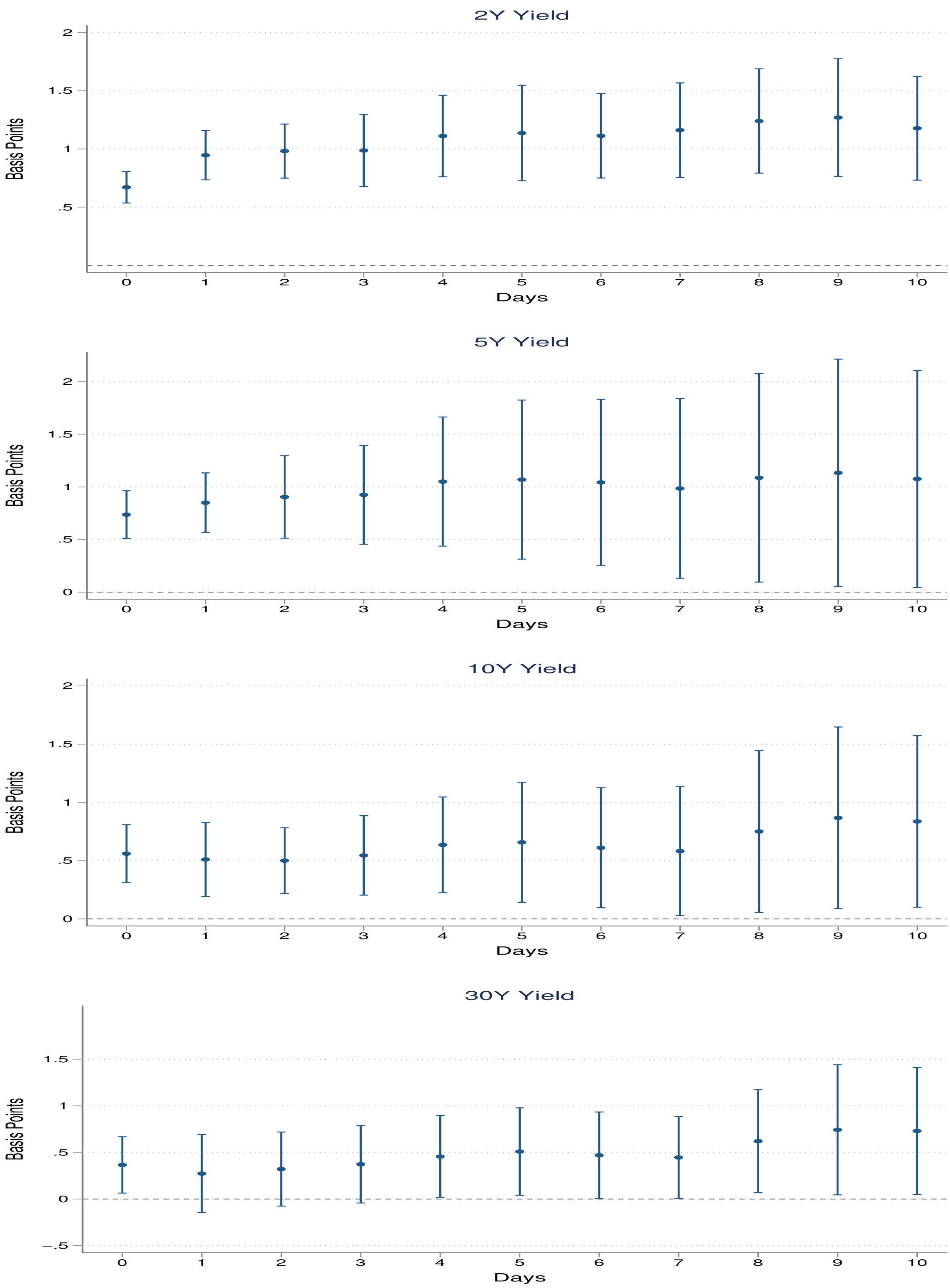
Persistence

In addition to the initial reaction of asset prices to policy rate surprises, policymakers are interested in the persistence of the response. One way to address this issue, and assess the robustness of the results, is to re-estimate equation (2.1) but with the change in the dependent variable calculated over subsequent days after a monetary policy announcement.[28] Figures 2.3 and 2.4 show the persistence of the exchange rate and the yield curve, respectively.

Since this exercise involves daily frequencies, figure 2.3 illustrates the exchange rate puzzle in Kohlscheen (2014) from a different angle since the currencies of advanced economies do exhibit persistence over subsequent days (Rosa, 2011b; Ferrari et al., 2017). Meanwhile, figure 2.4 shows that the flattening of the yield curve highlighted before con-

[28]Note that there is no overlap between observations because the announcements are always more than ten days—the maximum days used in the figure—apart from each other, see appendix 2.A.

Figure 2.4. Persistence of the Yield Curve Response to Policy Rate Surprises



Notes: This figure plots the coefficient estimates and 95% confidence intervals for the response of the 2-, 5-, 10- and 30-year yield changes to policy rate surprises. Yield changes are calculated from close of day $t-1$ to day $t+k$, where t is a day with a monetary policy announcement and $k = 0, 1, \dots, 10$. The announcements are always more than ten days apart from each other, see appendix 2.A. The sample includes all regular monetary policy announcements from January 2011 to December 2019.

tinues in the days following a policy rate tightening. The response of 2- and 5-year yields increases over time, while for 10- and 30-year yields the response is relatively more stable.

2.4 Solving the High-Frequency Exchange Rate Puzzle

This section argues that the apparent lack of response of the exchange rate to monetary policy in emerging markets illustrated in table 2.3 is due to measurement error in the daily returns of the exchange rate.

The key insight from comparing tables 2.2 and 2.3 is that one reaches different conclusions about the response of the exchange rate depending on the data frequency used. With intraday data, the currency appreciates following a tightening, a response that is consistent with standard open economy models and with the literature for advanced economies. This finding is relevant given the importance of the exchange rate in the transmission of monetary policy in small open economies. In contrast, the currency does not respond to the policy rate when daily data is used, what Kohlscheen (2014) coined as the high-frequency exchange rate puzzle in emerging economies. This phenomenon indeed seems characteristic of emerging markets since the reaction of the currencies of advanced economies can still be seen with daily data (Wright, 2012; Ferrari et al., 2017).

2.4.1 Validation Study

It is helpful to think about the puzzle from an errors-in-variables perspective. The availability of intraday and daily data allows me to conduct what is known as a validation study (Bound et al., 1994). Intraday changes are treated as the true surprises, whereas daily changes are seen as the pure surprises plus measurement error because they capture all news happening during a day. From this perspective, the analysis using daily data involves measurement error in *both* the dependent and independent variables. In the rest of the analysis, the dependent variable is the exchange rate returns.

In the classical measurement error model, when only the independent variable is measured with error, the least squares estimator $\hat{\beta}_1$ is biased towards zero, commonly referred to as attenuation bias; but when there is measurement error only in the dependent variable, the estimator $\hat{\beta}_1$ is consistent albeit with a larger standard error. Here, the 'noisy' (daily) and 'true' (intraday) values for the dependent and independent variables are observed, so the measurement errors can also be treated as observed and thus used to test the traditional assumptions. The errors are calculated as the difference between daily and intraday changes in the variables.

In the data, the measurement error in the dependent variable is larger than that in the independent variable, as shown in appendix 2.D. Intuitively, monetary policy decisions are the main event for swap rates during announcement days, and so the measurement error in policy rate surprises is small. Meanwhile, a lot of factors other than monetary policy decisions affect the exchange rate that even a daily frequency is not enough to avoid their influence.[29] Appendix 2.D also shows that the assumptions behind the classical measurement error model are not satisfied in the data, and confirms that attenuation bias is indeed small, given that the measurement error in policy rate surprises is small.

Table 2.4 sheds light on the puzzle by exploiting the two lengths for the event window. Since the changes in the exchange rate and the 3-month swap rate are measured with (daily) and without (intraday) error, there are four possible combinations of the variables to estimate equation (2.1). The ideal case is when there is no measurement error in neither of the variables, the opposite instance happens when there is measurement error in both. These two cases are reported in the first columns of tables 2.2 and 2.3, respectively, and are reproduced in table 2.4 for ease of comparison.

Table 2.4 shows that the main reason behind the puzzle is noise in the daily returns of the exchange rate. In the first two columns, the dependent variable is measured without error, whereas the independent variable is also measured without error in the first column, and with error in the second. For the purpose of the validation study, the coefficient in the first column is treated as the true parameter, it shows that a tightening leads to

[29]In line with this, regressing daily on intraday values gives an R^2 of 0.96 for policy rate surprises and of 0.14 for the exchange rate. Also, remember that the standard deviation of the exchange rate returns almost doubles when the frequency goes from intraday to daily (see table 2.1).

Table 2.4. The Response of the Exchange Rate to Policy Rate Surprises

	Intraday FX		Daily FX	
PRS Intraday	-1.85**		-0.38	
	(0.89)		(1.38)	
PRS Daily		-1.66**		-0.080
		(0.81)		(1.34)
Observations	72	72	72	72
R-squared	0.18	0.15	0.00	0.00

Notes: This table shows the coefficient estimates in regressions of exchange rate returns (FX) on intraday (PRS Intraday) and daily (PRS Daily) changes in the 3-month swap rate. The returns are calculated with *intraday* data in the first two columns and with *daily* data in the last two. Daily changes are calculated around monetary policy announcements; intraday changes are calculated starting 10 minutes before to 20 minutes after an announcement. The sample includes all regular monetary policy announcements from January 2011 to December 2019. Figures are expressed in basis points. No constant is included in the regressions. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

an appreciation of the currency, as discussed above. The second column meanwhile not only confirms an upward bias (since the 'true' parameter is lower) but shows how much measurement error in the independent variable biases the coefficient towards zero. One can see that attenuation bias is relatively small. Thus, the effect of policy rate surprises on the currency is significant and relevant even when they are measured with error.

In the last two columns of table 2.4, the dependent variable is now measured with error. As can be seen, in both columns there is an upward bias in $\hat{\beta}$, which is in fact larger than the one in the second column. Moreover, the standard error increases by more than 55%. So, measurement error in the returns of the exchange rate would lead one to incorrectly conclude that there is no significant effect of the policy rate on the exchange rate.

Pennings et al. (2015) suggest that the weaker response of the exchange rate in emerging markets relative to advanced economies could be driven by less liquid financial markets or more noisy measurement of monetary policy surprises. The evidence in table 2.4 indicates that, instead of measurement error in the policy rate surprises, the reason behind the puzzle is measurement error in the returns of the exchange rate.

The explanation of the puzzle lies on omitted variables. In the data, the measurement error in the daily exchange rate returns is not systematically related to surprises in the policy rate.[30] Therefore, rather than being correlated with the independent variable, the measurement error in the daily exchange rate returns is capturing the effects of other variables influencing the currency, giving rise to a standard omitted variable bias. Appendix 2.D extends the classical model to explain the inconsistency in the estimator as a result of measurement error in the dependent variable.

2.4.2 Potential Omitted Variables

To understand the other factors influencing the daily returns of the exchange rate, it is particularly important in the case of emerging markets to look at external—in addition to local—events when considering omitted variable candidates. The U.S. dollar responds significantly to different U.S. macroeconomic news (Faust et al., 2007). If those news happen to be released on days in which Banxico announces monetary policy decisions, daily returns of the peso per U.S. dollar exchange rate will reflect at least those two events. As appendix 2.A shows, it is indeed common for Banxico's monetary policy announcements to coincide with releases of relevant U.S. macroeconomic news.

U.S. labor market data is a good example of an omitted variable for the daily returns of the exchange rate. The change in nonfarm payrolls is released monthly by the U.S. Department of Labor generally on a Friday at 8:30 a.m. ET. Between 2004 and 2014, Banxico's announcements coincided with releases of nonfarm payrolls on 13 occasions, in four of them the average difference between the daily and intraday returns of the exchange rate exceeded 115 basis points, compared to 48 basis points for the whole sample.[31]

Consider, for instance, the announcement on September 6, 2013, in which Banxico unexpectedly cut its policy rate by 25 basis points. According to the estimation results with intraday data, this would have *depreciated* the currency by close to 50 basis points, but the peso actually *appreciated* 168 basis points during the day.[32] On this regard, it is worth noting that earlier that day, at 8:30 a.m. ET, nonfarm payrolls data for the

[30] In unreported regressions of the error on the surprises, the slope coefficient is not significant.
[31] Those dates are: March 8, 2013; September 6, 2013; December 6, 2013; December 5, 2014.
[32] In the 30-minute window around Banxico's announcement, the peso appreciated only 15 basis points.

previous month was released. Job gains were less than expected according to survey forecasts (169,000 vs 180,000), which analysts interpreted as evidence that it would take the Fed longer than previously anticipated to remove the monetary stimulus it suggested earlier in the year—what is known as the taper tantrum. Asset prices in turn reacted as if there was a loosening surprise in the U.S. policy rate, depreciating the U.S. dollar (and appreciating the Mexican peso).

More generally, a lot of factors other than monetary policy decisions affect the exchange rate that even a daily frequency is not enough to prevent their influence. Using intraday data—at least for the exchange rate—avoids this problem. Especially since the timing change of Banxico's announcements in 2015—from 10 a.m. ET Fridays to 2 p.m. ET Thursdays—made their coincidence with U.S. macroeconomic releases a certainty. Initial jobless claims in the U.S. are released every Thursday at 8:30 a.m. ET.

There are nonetheless other potential variables that can influence the exchange rate within a day. For instance, controlling for surprises in initial jobless claims, nonfarm payrolls and the unemployment rate in the U.S. calculated with data on survey expectations from Money Market Services, the effect of policy rate surprises (measured with and without error) on the daily returns of the exchange rate indeed increases in absolute terms (the estimated values are further to the left than the ones reported in the last two columns in table 2.4) and the standard error shrinks, but these changes are not enough to detect a significant effect.

Summing up, measurement error in the daily returns of the exchange rate causes not only imprecision in the estimation—as in the classical model—but also bias due to omitted variables. Even if policy rate surprises are measured without error, the noise in the daily exchange rate returns blurs the response of the currency to the policy rate.

2.5 Concluding Remarks

This paper uses a new dataset to quantify the effects of monetary policy on the exchange rate and bond yields in an emerging economy. Surprises in the policy rate have significant effects on asset prices. An unanticipated increase in the policy rate appreciates the currency and flattens the yield curve. The currencies of emerging markets are thus no different to those in advanced economies in terms of their responsiveness to the domestic policy rate. Meanwhile, policy rate surprises have a larger influence on the yield curve in Mexico than in the U.S., likely reflecting a relatively higher degree of long-term inflation uncertainty in Mexico.

This paper finds that the lack of response of the exchange rate in emerging markets found so far in the literature is the result of wide event windows. The response can only be perceived using intraday data for the exchange rate. Notice that the sensitivity of the response of the currency to data frequency does not mean that monetary policy is not important. It means that surprises in the policy rate are small enough that their effect on the exchange rate can only be seen in intraday windows. Banxico, like other central banks, works hard to communicate information to the market ahead of time so that, by the time of an announcement, most of it is already expected.

The results in this paper can be extended in different directions. Monetary policy in advanced economies has more than one dimension since asset prices react not only to surprises in the policy rate but also to changes in policy statements and asset purchase programs (Gürkaynak et al., 2005; Swanson, 2018; Altavilla et al., 2019). A relevant question is whether the multidimensionality of monetary policy in advanced economies is a feature shared by emerging markets. Solís (2021a) shows that monetary policy in Mexico is indeed multidimensional. Nonetheless, more work is needed to see whether this result is observed more broadly among emerging markets.

Understanding the transmission of monetary policy to financial markets is the starting point. The ultimate goal is to understand the real effects of monetary policy. However, it is hard to measure the persistence of policy surprises; Wright (2012) proposes a solution by imposing parametric restrictions in a vector autoregression. Relatedly, the policy rate surprises in this paper can be used as external instruments in a structural vector autoregression (known as proxy-SVAR or SVAR-IV) to identify the effects of monetary policy on macroeconomic variables (see Li and Zanetti, 2016; Stock and Watson, 2018).

Appendix 2.A Calendar of Monetary Policy Announcements

This appendix contains the calendar of Banxico's monetary policy announcements along with relevant macroeconomic data from Mexico[33] and the U.S. released on the same dates. Data releases are obtained from Bloomberg.[34]

Regarding the timing of the announcements, since 2007 the usual one-hour time difference between the capitals of Mexico and the U.S. widens to two hours during some Daylight Saving Time (DST) days. Before 2007, the one-hour difference was constant throughout the year because both countries followed the same DST arrangements. DST in both countries began on the first Sunday in April and ended on the last Sunday of October.[35] Starting in 2007, the U.S.—but not Mexico—extended its usage of the DST time, going from the second Sunday of March to the first Sunday of November.

When Banxico's announcements are made between the second Sunday of March and the first Sunday of April, and between the last Sunday of October and the first Sunday of November, the relevant Eastern Time (ET) zone times are 11 a.m. (up until 2014) and 3 p.m. (starting in 2015). Seven announcements happened in those weeks prior to 2015 (at 11 a.m. ET) and five afterwards (at 3 p.m. ET) for a total of 12 cases. It is also more likely to observe those meetings in the Spring than in the Fall since there is a two- to three-week gap in the former relative to a one-week gap in the latter. In fact, only 2 of the 12 cases fell in October.

On July 1, 2015, Banxico rescheduled the last four monetary policy announcements of that year to one or two business days after the Fed's announcements in anticipation to the first increase in the U.S. policy rate since the start of the Great Recession. In 2020, all Banxico's policy meetings were scheduled one or two weeks after those of the Fed.

[33]Between 2007 and 2012, there was a shift in the time of macroeconomic releases in Mexico, most of them were initially released during the afternoon, now they are released in the morning.

[34]The abbreviations and acronyms used in table 2.A.1 are as follows: ET is Eastern Time, GDP is gross domestic product, UoM refers to University of Michigan, IGAE is the global economic activity index, IP is industrial production, CPI is the consumer price index, PPI is the producer price index.

[35]The only exception is 2001, when lawmakers in Mexico shortened the duration of the DST period.

Table 2.A.1. Calendar of Monetary Policy Announcements

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
23-Jan-2004	10:00	MX: Trade Balance.
20-Feb-2004	10:00	MX: IGAE. US: CPI.
12-Mar-2004	10:00	US: UoM Sentiment.
26-Mar-2004	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
23-Apr-2004	10:00	MX: Trade Balance. US: Durable Goods Orders.
27-Apr-2004	10:00	US: Consumer Confidence.
28-May-2004	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
25-Jun-2004	10:00	MX: IGAE. US: GDP, UoM Sentiment.
23-Jul-2004	10:00	MX: Trade Balance.
27-Aug-2004	10:00	US: GDP, UoM Sentiment.
24-Sep-2004	10:00	MX: IGAE. US: Durable Goods Orders.
22-Oct-2004	10:00	MX: Bi-Weekly CPI, Retail Sales.
26-Nov-2004	10:00	
10-Dec-2004	10:00	US: UoM Sentiment.
28-Jan-2005	10:00	US: GDP.
25-Feb-2005	10:00	US: GDP, Existing Home Sales.
23-Mar-2005	10:00	MX: Trade Balance. US: CPI, Mortgage Applications, Existing Home Sales.
22-Apr-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
27-May-2005	10:00	MX: Unemployment. US: UoM Sentiment, Personal Income, Personal Spending.
24-Jun-2005	10:00	MX: Unemployment. US: Durable Goods Orders, New Home Sales.
22-Jul-2005	10:00	MX: Bi-Weekly CPI, Trade Balance.
26-Aug-2005	10:00	US: UoM Sentiment.
23-Sep-2005	10:00	MX: Trade Balance.
28-Oct-2005	10:00	US: GDP, UoM Sentiment.
25-Nov-2005	10:00	
09-Dec-2005	10:00	MX: Trade Balance. US: UoM Sentiment.
27-Jan-2006	10:00	US: GDP, New Home Sales.
24-Feb-2006	10:00	MX: IGAE, Current Account. US: Durable Goods Orders.
24-Mar-2006	10:00	MX: IGAE. US: Durable Goods Orders, New Home Sales.
21-Apr-2006	10:00	MX: Retail Sales.
26-May-2006	10:00	MX: Retail Sales, Current Account. US: UoM Sentiment, Personal Income, Personal Spending.
23-Jun-2006	10:00	MX: Trade Balance. US: Durable Goods Orders.
28-Jul-2006	10:00	US: GDP, UoM Sentiment.
25-Aug-2006	10:00	MX: IGAE, Current Account.
22-Sep-2006	10:00	MX: Bi-Weekly CPI, Retail Sales.
27-Oct-2006	10:00	US: GDP, UoM Sentiment.
24-Nov-2006	10:00	MX: Retail Sales, Current Account.
08-Dec-2006	10:00	MX: Trade Balance. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate.
26-Jan-2007	10:00	US: Durable Goods Orders, New Home Sales.
23-Feb-2007	10:00	MX: Trade Balance, Current Account.
23-Mar-2007	11:00	MX: Trade Balance. US: Existing Home Sales.
27-Apr-2007	10:00	US: GDP, UoM Sentiment.
25-May-2007	10:00	MX: Unemp. Rate, Current Account. US: Existing Home Sales.
22-Jun-2007	10:00	MX: Bi-Weekly CPI, Retail Sales.
27-Jul-2007	10:00	US: GDP, UoM Sentiment.
24-Aug-2007	10:00	MX: Unemp. Rate, Current Account. US: Durable Goods Orders, New Home Sales.
21-Sep-2007	10:00	MX: Unemp. Rate.
26-Oct-2007	10:00	MX: IGAE. US: UoM Sentiment.
23-Nov-2007	10:00	MX: Trade Balance, Current Account.
07-Dec-2007	10:00	MX: CPI, Gross Fixed Investment. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate.
18-Jan-2008	10:00	US: UoM Sentiment.
15-Feb-2008	10:00	US: UoM Sentiment, IP.
14-Mar-2008	11:00	US: CPI, UoM Sentiment.
18-Apr-2008	10:00	MX: Unemp. Rate.
16-May-2008	10:00	US: UoM Sentiment, Housing Starts.
20-Jun-2008	10:00	MX: Unemp. Rate.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
18-Jul-2008	10:00	MX: Unemp. Rate.
15-Aug-2008	10:00	US: UoM Sentiment, IP.
19-Sep-2008	10:00	MX: Unemp. Rate.
17-Oct-2008	10:00	MX: IP. US: UoM Sentiment, Housing Starts.
28-Nov-2008	10:00	
16-Jan-2009	10:00	MX: IP. US: CPI, UoM Sentiment, IP.
20-Feb-2009	10:00	MX: GDP. US: CPI.
20-Mar-2009	11:00	MX: Aggregate Supply and Demand.
17-Apr-2009	10:00	MX: IP. US: UoM Sentiment.
15-May-2009	10:00	US: CPI, UoM Sentiment, IP.
19-Jun-2009	10:00	MX: Aggregate Supply and Demand.
17-Jul-2009	10:00	MX: IP. US: Housing Starts.
21-Aug-2009	10:00	MX: Retail Sales. US: Existing Home Sales.
18-Sep-2009	10:00	
16-Oct-2009	10:00	US: UoM Sentiment, IP.
27-Nov-2009	10:00	
15-Jan-2010	10:00	US: CPI, UoM Sentiment, IP.
19-Feb-2010	10:00	US: CPI.
19-Mar-2010	11:00	MX: Aggregate Supply and Demand.
16-Apr-2010	10:00	US: UoM Sentiment, Housing Starts.
21-May-2010	10:00	MX: Retail Sales.
18-Jun-2010	10:00	MX: Retail Sales.
16-Jul-2010	10:00	US: CPI, UoM Sentiment.
20-Aug-2010	10:00	MX: GDP, IGAE.
24-Sep-2010	10:00	US: Durable Goods Orders, New Home Sales.
15-Oct-2010	10:00	US: CPI, UoM Sentiment, Retail Sales.
26-Nov-2010	10:00	
21-Jan-2011	10:00	MX: Unemp. Rate.
04-Mar-2011	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate, Factory Orders.
15-Apr-2011	10:00	US: CPI, UoM Sentiment, IP.
27-May-2011	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
08-Jul-2011	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Aug-2011	10:00	US: GDP, UoM Sentiment.
14-Oct-2011	10:00	US: UoM Sentiment, Retail Sales.
02-Dec-2011	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
20-Jan-2012	10:00	US: Existing Home Sales.
16-Mar-2012	11:00	US: CPI, UoM Sentiment, IP.
27-Apr-2012	10:00	MX: Trade Balance. US: GDP, UoM Sentiment.
08-Jun-2012	10:00	MX: Gross Fixed Investment.
20-Jul-2012	10:00	MX: Unemp. Rate.
07-Sep-2012	10:00	MX: CPI, Bi-Weekly CPI. US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Oct-2012	10:00	US: GDP, UoM Sentiment.
30-Nov-2012	10:00	US: Personal Income, Personal Spending.
18-Jan-2013	10:00	US: UoM Sentiment.
08-Mar-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, Unemp. Rate.
26-Apr-2013	10:00	MX: Trade Balance. US: GDP, UoM Sentiment.
07-Jun-2013	10:00	MX: CPI, Bi-Weekly CPI. US: Change in Nonfarm Payrolls, Unemp. Rate.
12-Jul-2013	10:00	MX: IP. US: UoM Sentiment.
06-Sep-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, Unemp. Rate.
25-Oct-2013	10:00	MX: Trade Balance. US: UoM Sentiment, Durable Goods Orders.
06-Dec-2013	10:00	MX: Gross Fixed Investment. US: Change in Nonfarm Payrolls, UoM Sentiment, Unemp. Rate, Personal Income, Personal Spending.
31-Jan-2014	10:00	US: UoM Sentiment, Personal Income, Personal Spending.
21-Mar-2014	11:00	MX: Retail Sales.
25-Apr-2014	10:00	MX: IGAE. US: UoM Sentiment.
06-Jun-2014	10:00	US: Change in Nonfarm Payrolls, Unemp. Rate.
11-Jul-2014	10:00	MX: IP.
05-Sep-2014	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate.

Date	ET	Macroeconomic Data from Mexico and the U.S. Released on the Same Day
31-Oct-2014	11:00	US: UoM Sentiment, Personal Income, Personal Spending.
05-Dec-2014	10:00	MX: Consumer Confidence. US: Change in Nonfarm Payrolls, Unemp. Rate, Factory Orders.
29-Jan-2015	14:00	US: Initial Jobless Claims.
26-Mar-2015	15:00	US: Initial Jobless Claims.
30-Apr-2015	14:00	US: Initial Jobless Claims, Personal Income, Personal Spending.
04-Jun-2015	14:00	US: Initial Jobless Claims.
30-Jul-2015	14:00	US: Initial Jobless Claims, GDP.
21-Sep-2015	14:00	US: Existing Home Sales.
29-Oct-2015	15:00	US: Initial Jobless Claims, GDP.
17-Dec-2015	14:00	US: Initial Jobless Claims.
04-Feb-2016	14:00	MX: Gross Fixed Investment. US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
17-Feb-2016	12:17	(Omitted)
18-Mar-2016	15:00	MX: Aggregate Supply and Demand. US: UoM Sentiment.
05-May-2016	14:00	US: Initial Jobless Claims.
30-Jun-2016	14:00	US: Initial Jobless Claims.
11-Aug-2016	14:00	MX: IP. US: Initial Jobless Claims.
29-Sep-2016	14:00	US: Initial Jobless Claims, GDP.
17-Nov-2016	14:00	US: CPI, Initial Jobless Claims, Housing Starts.
15-Dec-2016	14:00	US: CPI, Initial Jobless Claims, Manufacturing PMI.
09-Feb-2017	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
30-Mar-2017	15:00	US: Initial Jobless Claims, GDP.
18-May-2017	14:00	US: Initial Jobless Claims.
22-Jun-2017	14:00	MX: Bi-Weekly CPI. US: Initial Jobless Claims.
10-Aug-2017	14:00	US: Initial Jobless Claims, PPI.
28-Sep-2017	14:00	US: Initial Jobless Claims, GDP.
09-Nov-2017	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
14-Dec-2017	14:00	US: Initial Jobless Claims, Retail Sales, Manufacturing PMI.
08-Feb-2018	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
12-Apr-2018	14:00	US: Initial Jobless Claims.
17-May-2018	14:00	US: Initial Jobless Claims.
21-Jun-2018	14:00	US: Initial Jobless Claims.
02-Aug-2018	14:00	US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
04-Oct-2018	14:00	MX: Consumer Confidence. US: Initial Jobless Claims, Durable Goods Orders, Factory Orders.
15-Nov-2018	14:00	US: Initial Jobless Claims, Retail Sales.
20-Dec-2018	14:00	MX: Retail Sales. US: Initial Jobless Claims.
07-Feb-2019	14:00	MX: CPI, Bi-Weekly CPI. US: Initial Jobless Claims.
28-Mar-2019	15:00	US: Initial Jobless Claims, GDP.
16-May-2019	14:00	US: Initial Jobless Claims, Housing Starts.
27-Jun-2019	14:00	MX: Trade Balance. US: Initial Jobless Claims, GDP.
15-Aug-2019	14:00	US: Initial Jobless Claims, Retail Sales, IP.
26-Sep-2019	14:00	MX: IGAE. US: Initial Jobless Claims, GDP.
14-Nov-2019	14:00	US: Initial Jobless Claims, PPI.
19-Dec-2019	14:00	US: Initial Jobless Claims, Existing Home Sales.

Appendix 2.B Exclusion of the Announcement on Feb. 17, 2016

On January 20, 2016, the price of oil declined to 26 dollars per barrel (dpb), a level not seen since 2003. By February 4, the day of the first regular monetary policy meeting of

Banxico that year, the price recovered to 32 dpb. One week later, however, the price declined again, now to 28 dpb, raising concerns about the current account in Mexico and the fiscal position of the government, who relies considerably on oil exports. During that week, the peso depreciated to 19.2 pesos per dollar—a level not seen before—which raised concerns in Banxico about the exchange rate pass-through to inflation.

Shortly after 12 p.m. on February 17, the Finance Secretary and the Governor of Banxico held a joint press conference to announce a series of measures intended to provide confidence to market participants. The measures included a 50 basis point increase in the policy rate. Although the decision was completely unexpected by market participants, it was preceded and followed by other measures during the press conference, including fiscal adjustments. As a consequence, the response of asset prices around this particular monetary policy decision is likely to be contaminated by the other announcements; that is, identification of the actual effects of the emergency meeting is not easy, even using intraday data. Additionally, Banxico's decision to tighten was mainly influenced by the developments in the foreign exchange market in the previous days and, therefore, not completely exogenous. Finally, the statement of Banxico's emergency meeting that took place the day before the joint press conference clearly indicates that the decision to raise the policy rate 'does not start a tightening cycle'. The announcement can therefore be considered as a one-off policy rate surprise. For all these reasons the announcement of February 17, 2016 is excluded from the analysis.

Appendix 2.C Policy Rate Surprises Based on the TIIE28D

There are several considerations that need to be taken into account if the TIIE28D were to be used to measure monetary policy surprises. First, it is calculated once a day and thus daily changes are the highest frequency for which TIIE28D can be used, which is relevant given the 'high-frequency' exchange rate puzzle (see section 2.4).

Second, there is a difference between the date of the calculation and that of the publication, which needs to be taken into account to compute the daily changes. The relevant one is the calculation date since it reflects the available information in the market at the time when banks submit their quotes to Banxico for it to calculate the TIIE28D.[36] Given this timing difference, the data source for the TIIE28D matters. Bloomberg reports the series for the TIIE28D using the calculation date, while Banxico reports the series using the publication date.

One last consideration involves the timing change of Banxico's monetary policy announcements from 10 a.m. to 2 p.m. ET that started in 2015. The TIIE28D is calculated at 1 p.m. ET with quotes from at least six commercial banks.[37] This time falls in between the times of the monetary policy announcements preceding and following the timing change. Therefore, the daily changes using the TIIE28D series need to take this into account to ensure that they are correctly capturing the information before and after each monetary policy announcement. Specifically, prior to 2015, the daily changes need to be calculated as the difference in the series the day of the announcement relative to the previous day, but starting in 2015, they need to be obtained as the difference in the series the following day of the announcement relative to the day of the announcement.

The correlation between the policy rate surprises obtained from the daily change in the TIIE28D and that obtained from the intraday change in the 3-month swap rate is 0.7. Consistent with the explanation for the 'high-frequency' exchange rate puzzle in section 2.4, when policy rate surprises based on the daily change in the TIIE28D are used to estimate equation (2.1), there is no effect on the exchange rate.

[36] Daily changes obtained using the date of the publication do not capture the event of interest (i.e. surprises in monetary policy decisions) since they reflect information one day before the event.

[37] If less than six banks submit their quotes, the time for the calculation is delayed at most twice in 15-minute intervals. All these times increase by one hour during non-overlapping DST days between Mexico and the U.S., see section 2.2.1.

Appendix 2.D Derivation of Inconsistency in Slope Estimator

This appendix derives the degree of inconsistency in the slope estimator when there is an omitted variable, and measurement error in the dependent and independent variables.

Let μ_i, σ_i^2 and σ_{ij} denote respectively the expected value and variance of variable i, and the covariance between variables i and j. For ease of exposition, I assume that the dependent and independent variables in the following model have mean zero:

$$y^* = \beta x^* + \varepsilon,$$

in which the error ε is independent and identically distributed with zero mean, variance σ_ε^2 and uncorrelated with x^*, so $\mu_\varepsilon = \sigma_{\varepsilon x^*} = 0$. While both y^* and x^* are unobserved variables, y and x are observed but measured with an additive error:

$$x = x^* + u,$$

$$y = y^* + \nu,$$

in which the measurement errors have zero means and variances given by σ_u^2 and σ_ν^2, plus they are uncorrelated among themselves and with the error term ε; that is, $\mu_u = \mu_\nu = \sigma_{u\nu} = \sigma_{u\varepsilon} = \sigma_{\nu\varepsilon} = 0$. The estimated equation is thus:

$$y = \beta x + \tau = \beta x + \varepsilon - \beta u + \nu,$$

in which τ mixes together the 'true' error ε, and the measurement errors u and ν.

The classical measurement error model assumes that there is only measurement error in the independent variable, which is uncorrelated with the true dependent and independent variables; that is, $\sigma_u^2 > 0$ and $\sigma_\nu^2 = \sigma_{ux^*} = \sigma_{uy^*} = 0$. Under these assumptions, the classic result is that the least squares estimators for β and σ_ε^2, $\hat{\beta}$ and $\hat{\sigma_\varepsilon^2}$, are inconsistent. In particular, the estimator $\hat{\beta}$ is biased towards zero, commonly referred to as attenuation bias. The degree of inconsistency in $\hat{\beta}$ can be seen by taking its probability limit:

$$\text{plim}\left(\hat{\beta}\right) = \frac{cov(x, y^*)}{var(x)} = \frac{cov(x^* + u, \beta x^* + \varepsilon)}{var(x^* + u)} = \beta\frac{\sigma_{x^*}^2}{\sigma_{x^*}^2 + \sigma_u^2} = \beta\lambda,$$

Table 2.D.1. Assessment of Classic Measurement Error Assumptions

Measurement Error in	Classic Assumptions	Data	p-value
Independent Variable Only	$\sigma_\nu = 0$	59.96	
	$\rho_{ux^*} = 0$	0.02	0.856
	$\rho_{uy^*} = 0$	0.10	0.407
Dependent Variable Only	$\sigma_u = 0$	1.70	
	$\rho_{\nu x^*} = 0$	0.20	0.097
	$\rho_{\nu y^*} = 0$	-0.11	0.368
	$0 < \lambda < 1$	0.956	

Notes: This table compares the classic assumptions in measurement error models against the data. Measurement errors are calculated as the difference between daily and intraday changes in the variables. σ_i, σ_i^2 and ρ_{ij} denote the standard deviation and variance of variable i, and the correlation between variables i and j, respectively. Although the assumptions in the models are expressed in terms of covariances, this table reports correlations. The last column tests the null hypothesis of zero correlation. The attenuation factor is calculated according to $\lambda = \sigma_{x^*}^2 / \left(\sigma_{x^*}^2 + \sigma_u^2\right)$, where $\sigma_{x^*} = 7.93$. The sample includes all regular monetary policy meetings from January 2011 to December 2019.

in which λ is the attenuation factor, also known as the signal-to-total variance ratio.[38] Since $0 < \lambda < 1$, $|\text{plim}(\hat{\beta})| < |\beta|$. Hence, the extent of the bias depends asymptotically on λ; the farther away it is from one, the larger the attenuation bias.[39] Lastly, the estimator for the asymptotic variance s of $\hat{\beta}$ is also inconsistent.[40]

When there is measurement error in the dependent variable only, it is usually assumed to be uncorrelated with the true dependent and independent variables; that is, $\sigma_\nu^2 > 0$ and $\sigma_u^2 = \sigma_{\nu x^*} = \sigma_{\nu y^*} = 0$. These assumptions imply that the estimator $\hat{\beta}$ is consistent but with a larger standard error.

Validation studies provide evidence about the magnitude of the measurement errors and permit one to asses the validity of the classic assumptions for the case at hand. Table 2.D.1 compares the classic assumptions in measurement error models against the data for the exchange rate and the policy rate surprises.[41]

The measurement error in the independent variable is relatively small (σ_u is less than

[38] Notice that λ can also be defined as $\lambda = \sigma_{x^*}^2/\sigma_x^2$.

[39] When there is no measurement error in the independent variable, $\sigma_u^2 = 0$, $\lambda = 1$ and $\hat{\beta}$ is consistent.

[40] See Pischke (2007) for a derivation of $\text{plim}\,(\hat{s}) = \lambda s + \lambda(1-\lambda)\beta^2$, so when $\lambda = 1$, $\hat{s}$ is consistent.

[41] The null hypotheses $\mu_u = 0$ and $\mu_\nu = 0$ are not rejected. Also, the null hypothesis $\rho_{u\nu} = 0$ is not rejected; the sample correlation between the two measurement errors is 0.13 with a p-value of 0.28. The correlations of the measurement errors with the true error are not considered because a validation study allows one to observe u and ν but never ε, as pointed out by Bound et al. (1994).

2 basis points), so the attenuation factor is close to 1 and the attenuation bias is in turn relatively small asymptotically.[42] Most importantly, table 2.D.1 shows that the classical assumptions are not satisfied in the data. In particular, the measurement error in the dependent variable is quite high (σ_ν is close to 60 basis points) and is slightly correlated with the independent variable ($\rho_{\nu x^*} = 0.2$ is significant at the 10% level).

The main reason behind the puzzle is then noise in the daily exchange rate returns. The estimator $\hat{\beta}$ can be biased either because the error ν is systematically related to the independent variable—creating an endogeneity bias—or, more generally, because it captures the effects of other variables influencing the exchange rate—generating an omitted variable bias. To address both cases, the measurement error model is extended as follows:

$$y^* = \beta x^* + \gamma\omega + \varepsilon,$$

in which ω is the omitted variable (i.e. $\gamma \neq 0$) and it is assumed to be uncorrelated with ε and with the measurement errors u and ν. The measurement error in the dependent variable is now allowed to be correlated with the original independent variable; that is, $\sigma^2_\nu > 0$ and $\sigma_{\nu x^*} \neq 0$. With these assumptions, the degree of inconsistency in $\hat{\beta}$ is:

$$\text{plim}\left(\hat{\beta}\right) = \frac{cov(x, y)}{var(x)} = \frac{cov(x^* + u, \beta x^* + \gamma\omega + \nu + \varepsilon)}{var(x^* + u)} = \frac{\beta\sigma^2_{x^*} + \gamma\sigma_{\omega x} + \sigma_{\nu x}}{\sigma^2_{x^*} + \sigma^2_u}$$

$$\text{plim}\left(\hat{\beta}\right) = \beta\frac{\sigma^2_{x^*}}{\sigma^2_x} + \gamma\frac{\sigma_{\omega x}}{\sigma^2_x} + \frac{\sigma_{\nu x}}{\sigma^2_x} = \beta\lambda + \gamma\delta_{\omega x} + \delta_{\nu x}. \tag{2.2}$$

This result provides several insights. Now terms related to ω and ν also affect the inconsistency in $\hat{\beta}$.[43] Notice that $\delta_{\omega x}$ and $\delta_{\nu x}$ are the slope coefficients from regressing the omitted variable ω and the measurement error ν on the mismeasured covariate x, respectively.[44] Even without measurement error in the independent variable ($\lambda = 1$), the estimator $\hat{\beta}$ will still be biased whenever there is an omitted variable ($\gamma \neq 0$) and/or the measurement error in the daily exchange rate returns is correlated with the policy

[42] Since the attenuation factor is shared among the dependent variables (exchange rate and bond yields), there is also a relatively small attenuation bias in the estimated coefficients of the yield curve when intraday changes in yields are regressed on daily changes in the 3-month swap rate.

[43] Similarly, additional terms related to ω and ν appear in the probability limit of $\hat{s}$.

[44] If there is no measurement error in x ($\sigma^2_u = 0$), ω and ν are regressed on x^* instead of x.

rate surprises ($\sigma_{\nu x^*} \neq 0$). An illustration of this result can actually be seen in the third column of table 2.4. In that case, the second term in equation (2.2) would be a standard omitted variable bias whose magnitude and sign would depend on both the influence of the omitted variable on the exchange rate (γ) and the correlation of that variable with the policy rate surprises ($\delta_{\omega x}$). The third term in equation (2.2) would be an endogeneity bias created because $\rho_{\nu x^*} \neq 0$ (see table 2.D.1).

The second term in equation (2.2) cannot be assessed directly—because ω is unobserved—but the third term can be estimated as part of the validation study of section 2.4.1 and is indeed expected to be positive (since $\hat{\rho}_{\nu x^*} > 0$ in table 2.D.1). One can regress the error ν on the policy rate surprises (measured without and with error) to test whether they are systematically related. The respective coefficients $\hat{\delta}_{\nu x^*}$ and $\hat{\delta}_{\nu x}$ are positive (obtained from the coefficients already reported in table 2.4), but not significant. Therefore, rather than being correlated with the independent variable, the measurement error in the daily exchange rate returns is giving rise to an omitted variable bias.

Moreover, the bias due to an omitted variable can be characterized because its sign depends on the signs of γ and $\delta_{\omega x}$. Assume $\beta < 0$ and $\sigma_{\nu x} = 0$ in equation (2.2). An upward bias implies either $\gamma > 0$ and $\delta_{\omega x} > 0$, or $\gamma < 0$ and $\delta_{\omega x} < 0$. The first alternative actually aligns with the response of the exchange rate on September 6, 2013, described in section 2.4.2. In that case, the omitted variable (job gains) correlates positively with the policy rate surprises but has an offsetting effect on the exchange rate. For instance, when there is a surprise easing ($x < 0$) that depreciates the currency ($\beta < 0$), the omitted variable falls ($\omega < 0$ since $\delta_{\omega x} > 0$) appreciating the currency ($\gamma > 0$).

Chapter 3

Price and Quantity Effects of Monetary Policy Actions and Statements in an Emerging Economy

This chapter studies the effects of monetary policy actions and statements on the exchange rate, the yield curve and portfolio flows in Mexico.

3.1 Introduction

Monetary policy in advanced economies has more than one dimension since financial markets react to different types of information (e.g. changes in the policy rate, news about the future path of the policy rate, adjustments in asset purchase programs) communicated by central banks via policy statements. However, it is not yet clear whether monetary policy in emerging markets also has more than one dimension.[1] A lack of response of financial markets to the different types of information communicated by emerging market central banks would mean that they have less room to operate relative to their counterparts in advanced economies.

This paper studies whether asset prices and portfolio flows respond not only to changes

[1] Blinder et al. (2008) review the literature documenting the influence of central bank communications on financial markets mainly for advanced economies, although some evidence exists for emerging markets. Su et al. (2019) use content analysis to classify those communications but it is prone to subjectivity.

in the policy rate but to information about its future path communicated via policy statements by Banxico, the Mexican central bank. Monetary policy surprises are identified following the methodology proposed by Gürkaynak et al. (2005) and using a new dataset of intraday changes in swap rates around monetary policy announcements from 2011 to 2019.[2] Surprises in the policy rate and about its future path are henceforth referred to as target and path surprises, respectively. To measure the effects on asset prices, intraday changes over the same windows are also calculated for the exchange rate and bond yields. To assess the effects on portfolio flows, the analysis looks at holdings of Mexican government securities disaggregated by type of investor available daily and at U.S.-Mexico portfolio flows available monthly. The analysis quantifies the contemporaneous effects as well as their persistence in the days following a monetary policy announcement using an event study methodology and local projections, respectively. By now, event studies with high-frequency data are a well-established approach in macro-finance to overcome endogeneity concerns. Monetary policy is intrinsically endogenous, it reacts to different macroeconomic circumstances, and so quantifying its effects is challenging. Event studies overcome this by isolating the surprise component of policy decisions.[3]

The main finding in this paper is that path as well as target surprises are relevant for asset prices and portfolio flows in Mexico. This means that, in addition to changes in the policy rate, central banks in emerging markets also have the ability to manage expectations via statements. Three implications are worth highlighting. First, the multidimensionality of monetary policy (Gürkaynak et al., 2005; Swanson, 2018; Altavilla et al., 2019) is not exclusive to advanced economies. Second, by communicating information about the future path of the policy rate, emerging market central banks can better tame the spillover effects of monetary policy in advanced economies, which tend to be larger on long-term yields (Obstfeld, 2015; Kearns et al., 2018). Third, central banks in emerging markets would still have room to conduct monetary policy in case their policy rate were to be constrained by the zero lower bound.[4]

[2]The swaps reference an interbank interest rate that closely follows the policy rate.

[3]Nakamura and Steinsson (2018) review approaches to measure the effects of monetary policy.

[4]Gürkaynak et al. (2005) reach a similar conclusion for the U.S. before the global financial crisis. When the zero lower bound is binding, forward guidance about the policy rate is more explicit than under a

The exchange rate only reacts to target surprises and the effect is not persistent. The lack of response to path surprises seems characteristic of the Mexican peso because the currencies of advanced economies do respond to path surprises (Rosa, 2011b; Ferrari et al., 2017), and emerging market currencies other than the Mexican peso respond to U.S. path surprises (Hausman and Wongswan, 2011). Future research can explore the extent to which Banxico's foreign exchange interventions to provide liquidity and to promote orderly market conditions mute the response of the currency to path surprises.

Bond yields respond significantly to target and path surprises. In particular, medium- and long-term yields react more to path than to target surprises, consistent with the evidence for the U.S. reported by Gürkaynak et al. (2005) for a period when the U.S. policy rate was not constrained by the zero lower bound. In this sense, Banxico's influence over longer-term yields improves the implementation of monetary policy in Mexico given that medium- and long-term yields are more relevant to the spending decisions of households and firms. Moreover, both types of surprises have a larger influence on the yield curve in Mexico than U.S. surprises have on the U.S. yield curve. According to the expectations hypothesis, this result suggests that long-term inflation expectations in Mexico are less firmly anchored than in the U.S.;[5] even though inflation expectations in Mexico are anchored (De Pooter et al., 2014), it is likely that they are not as well anchored as in the U.S. In addition, the larger reaction in Mexico can also reflect a larger effect of surprises on term premia, which could be explained by the response of reach-for-yield investors (Hanson and Stein, 2015); Mexican banks indeed exhibit this behavior as explained next.

Daily portfolio flows respond to both target and path surprises. Banxico collects daily data on holdings of different types of Mexican government securities disaggregated by type of investor. The most relevant type of bonds in Mexico are the long-term fixed-rate ones known as bonos. The analysis shows that domestic and foreign investors rebalance their portfolios of bonos following monetary policy decisions. Moreover, the rebalancing done by domestic investors depends on their business model. For instance, banks exhibit

conventional approach (Kuttner, 2018). When other unconventional monetary policies are implemented (e.g. quantitative easing), financial markets respond to other types of information (Swanson, 2018).

[5]Since prices are flexible in the long run, long-term expected real interest rates would not be affected.

reach-for-yield behavior since they increase their purchases of bonos a few days after a target easing surprise; their response supports the mechanism described by Hanson and Stein (2015), in which monetary policy affects term premia due to yield-oriented investors. More broadly, holdings data provides a broader picture of the effects of monetary policy. Target and path surprises influence bond yields days after an announcement, which is in line with gradual changes in bonos holdings. Indeed, pension funds and foreign investors take time to respond to the surprises. This evidence is consistent with the slow-moving capital explanation proposed by Brooks et al. (2019) for how the yields respond to monetary policy in advanced economies.

Some portfolio flows between Mexico and the U.S. also react to target and path surprises. Inflows into non-U.S. stocks increase following a target easing surprise. This means that the central bank in the destination country can trigger a reach-for-yield behavior in U.S. investors. Meanwhile, inflows into U.S. agency bonds decrease after a path easing surprise, which suggests that local investors use non-Mexican securities to rebalance their portfolios in response to monetary policy decisions in Mexico. Lastly, the evidence suggests that foreign non-U.S. investors are important players in the bonos market. These results show that capital flows to emerging markets respond not only to the monetary policy of the home country, as shown in the existing literature, but also to the monetary policy of the destination country.

This paper contributes to the literature in two respects. First, it extends the analysis in Gürkaynak et al. (2005) to an emerging economy in order to assess the extent to which its path surprises impact, and for how long, asset prices as well as portfolio flows. The study of the effects of monetary policy in emerging markets generally focuses on target surprises (Kohlscheen, 2014; Solís, 2021c). Second, this paper takes the perspective of an emerging market economy to analyze the effects of its monetary policy on the portfolio flows it faces. In contrast, the traditional approach in the literature takes the perspective of the home country to study, for instance, the spillover effects of its monetary policies. The literature based on the traditional approach documents significant inflows into financial assets in emerging markets after the global financial crisis (Fratzscher et al., 2018).[6] Hausman and Wongswan (2011) show that stock prices respond more to U.S. target surprises, whereas exchange rates and long-term yields respond more to U.S. path surprises; meanwhile, short-term yields respond to both types of surprises. Bowman et al. (2015) and Fischer (2020) show that the effect of U.S. monetary policy surprises is particularly relevant for local currency sovereign yields.

The rest of the paper is structured as follows. The next section describes how monetary policy surprises are measured. Section 3.3 tests the number of monetary policy factors and discusses their interpretation. Sections 3.4 and 3.5 respectively analyze how asset prices and portfolio flows respond to the factors. The last section concludes.

3.2 Identification of Monetary Policy Surprises

The Bank of Mexico, also known as Banxico, conducts monetary policy through a Governing Board comprised by the governor—who acts as the chair of the Board—and four deputy governors. Banxico became an independent central bank in 1994 and adopted an inflation targeting regime in 2001. The official inflation target is 3% with a range of $\pm$ 1%. Before 2008, Banxico conducted monetary policy using something akin to a target for non-borrowed reserves, and in 2008 it adopted the overnight interbank interest rate as its monetary policy instrument. Solís (2021c) discusses institutional details about Banxico's monetary policy and provides the dates and times of its announcements.

This paper uses swap rates to measure surprises in monetary policy decisions. The swaps market in Mexico references an interbank interest rate denominated in local currency that serves as a benchmark for banking loans in the country and that closely follows the policy rate, the 28-day interbank interest rate or TIIE28D.[7] Banxico calculates the TIIE28D once a day based on quotes submitted by commercial banks. The TIIE28D 3-month swap is the main local derivative. Solís (2021c) uses this swap to capture surprises in the policy rate. This paper extends his analysis by considering a broader sense of

[6] Curcuru et al. (2015) argues that this is due to allocations of new savings (a wealth effect) rather than a reallocation toward assets in those countries since portfolio flows did not surge disproportionately to emerging markets in response to unconventional monetary policies in advanced economies.

[7] The average difference between the TIIE28D and the overnight policy rate is around 30 basis points.

monetary policy surprises given that the adoption of inflation targeting and well-anchored inflation expectations arguably allowed Banxico to pursue more forward-looking policies.

I consider swaps with maturities up to one year. Like other central banks, Banxico communicates information about its monetary policy outlook via statements. This information might influence market expectations about future policy actions. Unlike in many advanced economies after the global financial crisis, the policy rate in Mexico has so far not been constrained by the zero lower bound. As a consequence, Banxico's monetary policy statements include information about future policy actions within a year out at most, it does not need to commit to a predetermined path for the policy rate for longer periods. Using swaps with maturities up to one year is consistent with the approach of Gürkaynak et al. (2005) for the U.S. before the Great Recession.[8]

Monetary policy surprises are obtained as the difference in swap rates around windows containing policy announcements.[9] Intraday differences from 10 minutes before to 20 minutes after each announcement are calculated for swaps of 3, 6 and 9 months as well as of 1 year.[10] To measure the effects of the surprises, intraday differences over the same windows are also calculated for the Mexican peso (MXN) per U.S. dollar (USD) exchange rate and for yields of bonds issued by the Mexican government with maturities of 2, 5, 10 and 30 years.[11] [12] For yields, the change is calculated directly using quotes before and after the announcements; for the exchange rate, 100 times log differences are used to approximate the percentage change (or return) over the window. All the information for the analysis comes from Bloomberg. The information to calculate the intraday differences for the swap rates and the exchange rate is available since 2011, and since 2013 for bond yields other than the 5-year yield for which the sample starts in December 2014.

[8] Swanson (2018) argues for including maturities of more than one year out when the policy rate is constrained by the zero lower bound and the central bank uses unconventional monetary policy tools.

[9] See Solís (2021c) for considerations about the timing of the announcements.

[10] When no data is available at any of those times, the next available quote is used to compute the changes. In extreme cases, in which there are no quotes in wider windows for a day, the open and close quotes are used to compute the differences. This only happens on a few days for some swaps.

[11] The Mexican government issued 10- 20- and 30-year fixed-rate local-currency bonds for the first time in 2001, 2003 and 2006, respectively, following the implementation of a debt management strategy to develop its debt market that started in 2000 (Jeanneau and Tovar, 2008; Abreu, 2014).

[12] All the results discussed below using tight 30-minute windows remain using wider 50-minute windows, starting 20 minutes before and ending 30 minutes after each monetary policy announcement.

3.3 Monetary Policy Dimensions

This section applies the methodology proposed by Gürkaynak et al. (2005) to Mexico and shows that two factors in monetary policy decisions move asset prices. One factor can be associated with surprises about the current policy rate and the other factor with surprises about its future path communicated via policy statements. Subsequent sections analyze how asset prices and portfolio flows respond to these factors.

3.3.1 Assessing the Number of Factors

The number of factors influencing asset prices is assessed using the matrix rank test developed by Cragg and Donald (1997). Let X be a $T \times n$ matrix of asset price changes around monetary policy announcements with T observations and n asset prices, and with a factor structure given by:

$$X = F\Lambda + \zeta, \tag{3.1}$$

in which F is a $T \times k$ matrix with k unobserved factors, Λ is a $k \times n$ matrix of factor loadings and ζ is white noise. For a given number of variables n, the Cragg–Donald test assesses the null hypothesis that k_0 factors ($k_0 < n$) explain most of the variability observed in the data. The test minimizes the distance between the covariance matrix of the observed data and that obtained from all the possible models with k_0 factors. The test is a Wald statistic with an asymptotic χ^2 distribution with $(n - k_0)(n - k_0 + 1)/2 - n$ degrees of freedom. Inference based on it requires that $(n - k_0)(n - k_0 + 1)/2 > n$.[13]

In addition to conducting the test for the exchange rate and bond yields, the test is also performed for swaps with maturities up to one year because later on that helps to give a structural interpretation to the estimated factors. Since $n = 5$ for the exchange rate and the yields while $n = 4$ for swaps, k_0 can be at most 2 and 1, respectively, to satisfy the requirements of the test. To check robustness to the frequency of the data and the sample period, the test is also performed using daily—besides intraday—changes in asset prices around the announcements. Daily changes for all asset prices are calculated

[13] See Cragg and Donald (1997) and the appendix in Gürkaynak et al. (2005) for further details.

since 2004, except for the 30-year yield which starts in October 2006.

Table 3.1 shows that two factors characterize the responses of asset prices in Mexico. The null hypothesis of no factors is strongly rejected in all cases. Solís (2021c) indeed shows that asset prices in Mexico respond at least to unanticipated changes in the current policy rate. The most interesting null hypotheses, however, involve one and two factors, $k_0 = 1, 2$. When the test is performed for the exchange rate and bond yields, the null hypothesis of one factor is rejected at the 5% significance level, but the null of two factors cannot be rejected even at the 10% level. This finding does not depend on the frequency of the data nor the sample period. Therefore, asset prices in Mexico react to more than just surprises about the current policy rate, they react to additional information Banxico is providing. And they have done so even before Banxico adopted the overnight policy rate in 2008, since daily data goes back to 2004. The multidimensionality of monetary policy in advanced economies (Gürkaynak et al., 2005; Swanson, 2018; Altavilla et al., 2019) is thus also observed in emerging markets.

The same conclusion is reached when the test is performed for swaps. The null of one factor is also rejected at the 5% significance level, regardless of the data frequency. Section 3.3.3 exploits this for interpreting the two factors.

3.3.2 Estimating the Factors

The factors F, as well as their loadings Λ, in equation (3.1) are estimated by applying principal components to the matrix of asset price changes X. The two factors will be the first two principal components of X. These factors are orthogonal to each other and are linear combinations of the variables included in X. Yet the factors do not have a practical interpretation, which is needed to understand their effects on asset prices.

For interpretation purposes, X is comprised of swaps—instead of the exchange rate and bond yields—when estimating the two factors, F_1 and F_2. The factors are normalized to have unit standard deviation and then rotated to give them a structural interpretation.

Table 3.1. Tests of the Number of Factors in Monetary Policy Surprises

	Frequency	$H_0 : k = k_0$	Wald Statistic	Degrees of Freedom	p-value	Observations
Exchange Rate & Yield Curve	Intraday	0	36.55	10	0.000	41
		1	11.62	5	0.040	41
		2	0.04	1	0.851	41
	Daily	0	35.24	10	0.000	120
		1	14.60	5	0.012	120
		2	0.01	1	0.933	120
Swaps	Intraday	0	26.47	6	0.000	72
		1	7.47	2	0.024	72
	Daily	0	25.57	6	0.000	155
		1	9.49	2	0.009	155

Notes: This table reports the results from the Cragg–Donald test. H_0 is the null hypothesis of $k = k_0$ factors against the alternative of $k > k_0$ factors, where $k_0 = 0, 1, 2$. The sample is all regular monetary policy announcements until December 2019, the starting date varies based on data availability: for the exchange rate and the yield curve with intraday data is December 2014 (due to the 5-year yield) and with daily data is October 2006 (due to the 30-year yield); for swaps with intraday data is January 2011 and with daily data is January 2004. The yield curve includes 2- 5- 10- and 30-year bonds. Swaps include 3- 6- 9-month and 1-year swaps.

Let U be a 2×2 rotation matrix for F such that

$$Z = F\,U, \tag{3.2}$$

in which Z denotes the rotated factors, Z_1 and Z_2. Four restrictions are imposed on U to uniquely identify it and being able to give an interpretation to the factors. The rotated factors are required to be orthogonal to each other and to have unit variance. The final restriction is set so that only Z_1 mirrors the change in the 3-month swap rate, i.e. the policy rate surprise, thus the loading of the 3-month swap rate on Z_2 is zero.[14]

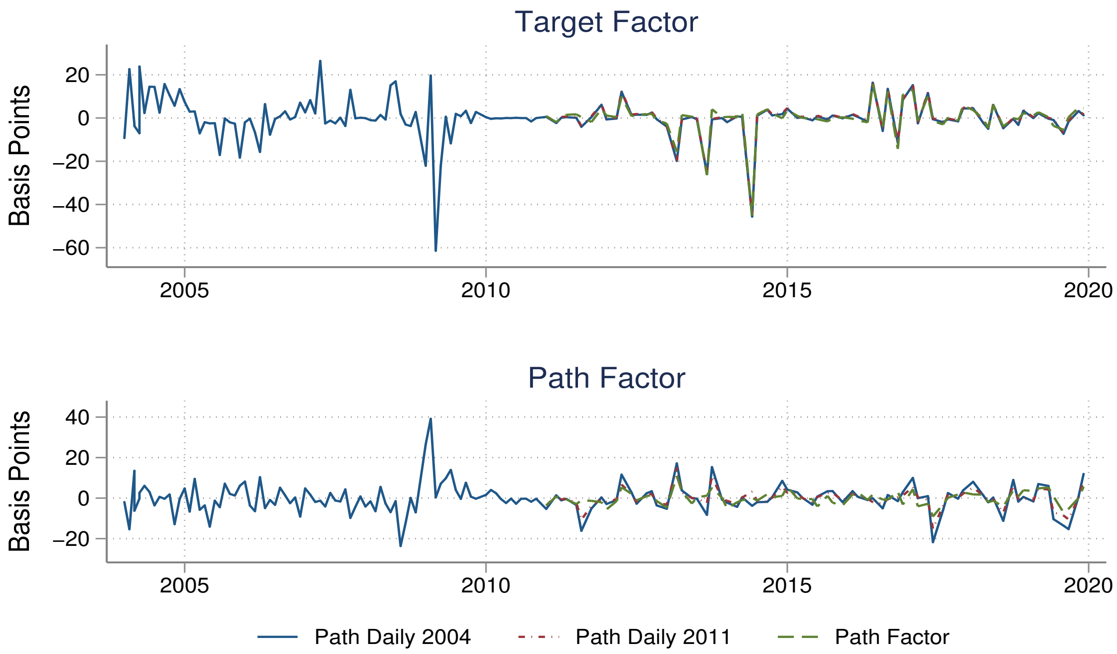
To further ease the interpretation and to be able to compare the magnitudes of the factors, they are rescaled so that Z_1 moves one-to-one with the change in the 3-month swap rate and Z_2 affects the 1-year swap rate in the same magnitude as Z_1 does. The rescaling is done using data since 2013, when intraday data for bond yields becomes available.[15] Table 3.A.1 in the appendix verifies that changes in the 3-month swap rate move (one-to-one) with Z_1, whereas Z_2 has considerable explanatory power for changes in the 1-year swap rate.

Figure 3.1 shows that the estimation of the factors is not sensitive to the sample size, the sample period nor data frequency. The figure compares the time series of Z_1 and Z_2 obtained with intraday and daily data since 2011 as well as with daily data since 2004. The Z_1 factors correlate among themselves around 0.98, whereas the Z_2 factors around 0.74. Even though daily data yields longer time series, the core of the analysis relies on the factors identified with intraday data because there are gains in precision during the estimation and in terms of explanatory power, plus the effects on the exchange rate can only be detected with intraday data (Solís, 2021c).

[14] The loadings on Z_1 and Z_2 for all four swaps can be expressed in terms of the parameters in U and the factor loadings Λ. To see this, substitute F from equation (3.2) into (3.1). The last restriction, however, only uses the two loadings in Λ for the 3-month swap. See the appendix in Gürkaynak et al. (2005).

[15] The rescaling does not affect the starting date of the factors, the first observation starts in 2011.

Figure 3.1. Monetary Policy Surprises in Mexico: Intraday and Daily Data



Notes: This figure compares the evolution of the target and path factors obtained with intraday and daily data. The solid lines are obtained with daily data from 2004 to 2019. The dash-dotted lines are obtained with daily data from 2011 to 2019. The dashed lines are obtained with intraday data from 2011 to 2019.

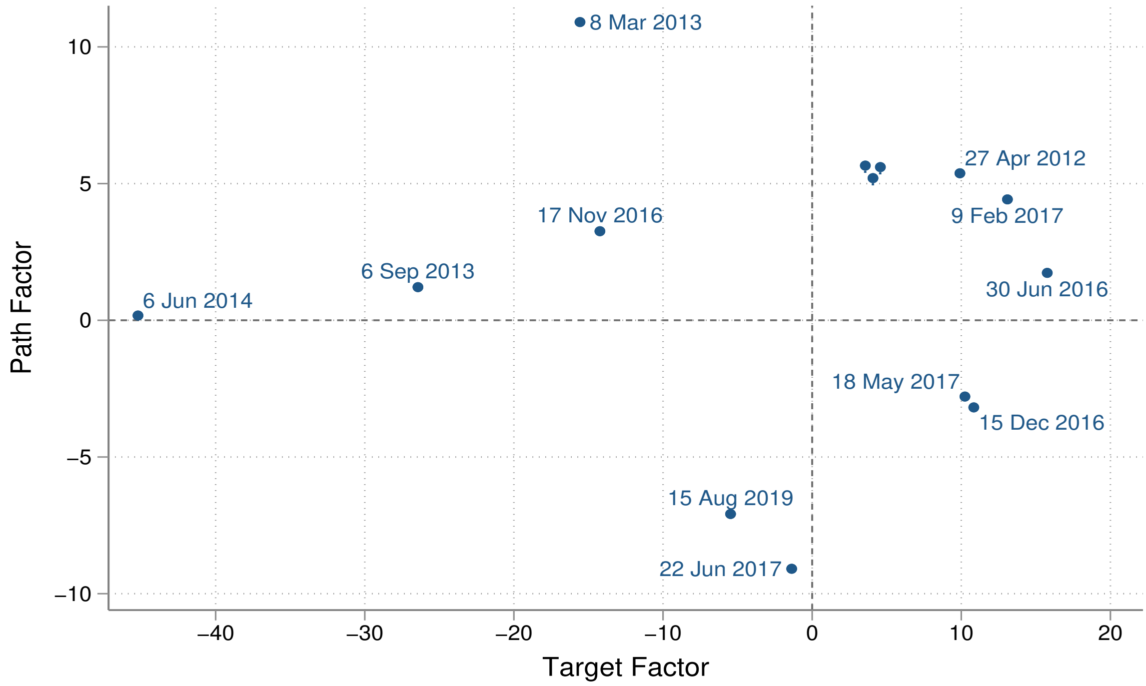
3.3.3 Interpreting the Factors

The factors Z_1 and Z_2 are henceforth referred to as the target and path factors or surprises, respectively. By definition, Z_1 moves with surprises in the 3-month swap rate, and Z_2 is aligned with surprises in the 1-year swap rate that are unrelated to changes in the 3-month swap rate.[16] Accordingly, Z_1 can be related to surprises in the *current* policy rate, while Z_2 can be associated with surprises about the *future* path of the policy rate. The evidence presented below supports this interpretation.

Figure 3.2 compares the estimated target and path surprises for relevant dates over the sample period. Even if there is no change in the policy rate, there can still be target surprises if market participants expected a change. For instance, on April 27, 2012, the average rate from survey expectations was lower than the existing level indicating that

[16]By construction, Z_1 is essentially the same as the policy rate surprises in Solís (2021c), the correlation coefficient between the two measures is 0.998. Meanwhile, the correlation between Z_2 and the residual of a regression of the change in the 1-year swap on the change in the 3-month swap is 0.993.

Figure 3.2. Monetary Policy Dimensions



Notes: This figure plots the largest estimated target and path factors obtained from intraday data, as explained in the main text. The sample is all regular monetary policy announcements from January 2011 to December 2019. The dates of the three unlabeled dots in the first quadrant are 25 Oct 2013 (bottom), 29 Jan 2015 (left) and 19 Dec 2019 (right).

some market participants expected a cut in the rate. Banxico, however, left the policy rate unchanged, which was interpreted as a target tightening surprise as the figure shows.

Statements and Path Surprises

Statements convey information intended to influence expectations about future monetary policy decisions and to reduce policy uncertainty. Table 3.2 summarizes Banxico's policy statements on announcement days in which, according to figure 3.2, their content communicated important information about the future path of the policy rate.

The excerpts reported in table 3.2 are in line with figure 3.2. The announcements on June 2017 and August 2019 suggested loose financial conditions ahead, while the statements for the rest of the announcements signaled a tighter monetary stance going forward. Moreover, the announcements on March and October 2013, January 2015 and June 2017 are noteworthy because of their explicit reference to the future path of the policy rate.

Table 3.2. Summary of Statements in Selected Dates

Date	Description
27-Apr-2012	Statement indicates that the balance of risks for economic growth has improved.
08-Mar-2013	Statement makes clear that the 50 basis point reduction in the policy rate 'does not represent the beginning of an easing cycle'.
25-Oct-2013	Statement highlights that 'no further cuts in the policy rate are appropriate in the foreseeable future'.
29-Jan-2015	Statement notes the recent depreciation of the peso is an upward risk to inflation; the Board will monitor U.S. monetary policy and exchange rate dynamics 'to be able to take the necessary measures'.
17-Nov-2016	Statement announces that the balance of risks for inflation has deteriorated and removes 'this increment in the policy rate is not the beginning of a tightening cycle' from the previous statement.
09-Feb-2017	Statement highlights the effects of the tightenings in 2016 and 'the ones required in 2017' to counteract inflationary pressures.
22-Jun-2017	Statement drops reference to do 'the necessary tightenings ahead' from the previous statement; the balance of risks for inflation has shifted from moderately deteriorated to neutral.
15-Aug-2019	Statement notes that the negative output gap increased more than expected.
19-Dec-2019	Statement notes that headline and core inflation for 2020 might be 'slightly higher' than previously expected due to a recent increase in minimum wages.

Consider the tightening cycle that started in mid-2016 due to rising inflation risks as an example of the association of path surprises with information contained in statements. The 2016 U.S. presidential election generated uncertainty about the bilateral relation of the two countries. Between early-November 2016 and mid-January 2017, the peso depreciated by more than 14%. In addition, the minimum wage was raised and gasoline subsidies ended in early-2017. By mid-2017, inflation had risen for 10 consecutive months. On June and September 2016, Banxico raised its policy rate by 50 basis points, more than had been expected according to surveys. These increases were followed by 6 consecutive tightenings, three of 50 basis points followed by three of 25 basis points.[17] In the statement for the last hike on June 2017, Banxico indicated that it expected inflation to peak in the near future, in addition to what is reported in table 3.2. This statement is relevant because the hike was mostly anticipated by the market, so there was essentially no target surprise, but the wording suggested the end of the tightening cycle, which can be interpreted as a path easing surprise. In fact, the closest to a 'pure' path surprise in the sample.

Two dates are also worth reviewing due to the 'lack' of path surprises. According to figure 3.2, the announcements on September 2013 and June 2014 contained large easing surprises in the target but not in the path factor. A closer look at the statements for those dates supports this interpretation. Contrary to survey expectations of no change in the monetary policy stance, on September 6, 2013, Banxico announced a 25 basis point cut in the policy rate but indicated that with 'the lower policy rate, the monetary stance is in line with inflation converging to the target.' Similarly, while survey expectations indicated no policy change on June 6, 2014, Banxico cut the policy rate by 50 basis points adding that 'no further reductions in the policy rate are expected in the foreseeable future.' In both decisions the policy rate was cut unexpectedly, but the statements portrayed them as one-off cuts by signaling that no further movements in the rate were to be expected. That is, they were both target but not path surprises.

These examples support the association of path surprises with unanticipated information about the future path of the policy rate communicated via statements. Notice,

[17]The beginning of the tightening cycle might be dated as of November 2016 according to table 3.2.

however, that the magnitude of the path surprises is lower than that of target surprises. The largest path surprises in Mexico are also lower compared to the largest path surprises for the U.S. reported by Gürkaynak et al. (2005), see their table 4. Two potential reasons might explain this. First, international developments play a relevant role in the monetary policy considerations of small open economies, and Mexico is no exception. In this sense, it is harder to commit to a future path of the policy rate for extended periods of time when there is high uncertainty abroad. Second, and most importantly, the possibility of reaching the zero lower bound has not been an issue in Mexico, and so the need of Banxico to rely on path surprises has been low.

3.4 The Effects of Monetary Policy on Asset Prices

The previous section shows that target and path surprises capture the responses of asset prices to monetary policy decisions. This section documents the response of the exchange rate and the yield curve to those surprises. The next section extends the analysis and assess their effects on portfolio flows.

3.4.1 Contemporaneous Effects

The following event-study regression is used to measure the on-impact effects of the two monetary policy surprises on the exchange rate and the yield curve:

$$\Delta y_t = \beta_0 + \beta_1 Target_t + \beta_2 Path_t + \varepsilon_t, \tag{3.3}$$

in which Δy_t is the intraday change in asset prices around monetary policy announcements, as described in section 3.2. The changes are expressed in basis points. $Target_t$ and $Path_t$ are the two factors described in section 3.3.3. Positive values in either factor indicate a tightening of the monetary stance and negative values represent an easing. Finally, the error term ε_t captures variations in the dependent variables unrelated to the two factors.

Table 3.3 reports the results. Since the target surprises in this paper are highly correlated with policy rate surprises in Solís (2021c), the estimated coefficients for target surprises in table 3.3 align closely with the responses of the exchange rate and the yield curve reported by Solís (2021c).

Response of the Exchange Rate

Table 3.3 indicates that the exchange rate only responds to target but not to path surprises. This seems puzzling since rational and forward-looking investors are expected to respond to changes in the future path of the policy rate. In fact, the currencies of advanced economies respond stronger to path than to target surprises (Rosa, 2011b; Ferrari et al., 2017). The lack of response to path surprises seems characteristic of the Mexican peso, however. For instance, other emerging market currencies respond to U.S. path surprises, whereas the peso only reacts to U.S. target surprises (Hausman and Wongswan, 2011).

Two reasons might explain the lack of response of the currency to path surprises. First, although the peso operates under a flexible regime, Banxico intervenes in the foreign exchange market to provide liquidity and to promote orderly conditions. Even though Banxico intervenes following a rules-based approach (García-Verdú and Zerecero, 2013),[18] the interventions might unintendedly be muting the response of the currency to path surprises. Consistent with this, Hausman and Wongswan (2011) find that the currencies of countries with a more flexible exchange rate regime respond more to path surprises (in the U.S.).

An alternative explanation involves an information channel, according to which path surprises have different effects on the currency that offset each other. For instance, a path tightening surprise would appreciate the currency due to a higher policy rate in the future but could, at the same time, depreciate it if the surprise signals higher future inflation. Gürkaynak et al. (2005) provide a similar explanation for the lack of reaction of the stock market to path surprises.

[18] For instance, Banxico intervenes following a 2% intraday depreciation threshold.

Table 3.3. Response of Asset Prices to Target and Path Surprises

	FX		2Y Yield		5Y Yield		10Y Yield		30Y Yield	
Target	-1.89**	-1.89**	0.67***	0.68***	0.35***	0.27***	0.42***	0.42***	0.30***	0.30***
	(0.77)	(0.78)	(0.086)	(0.081)	(0.10)	(0.094)	(0.086)	(0.081)	(0.079)	(0.075)
Path		-0.14		0.48***		0.69***		0.56***		0.59***
		(1.19)		(0.089)		(0.16)		(0.12)		(0.12)
Obs.	72	72	56	56	41	41	56	56	56	56
R^2	0.20	0.20	0.80	0.86	0.24	0.60	0.53	0.69	0.35	0.59

Notes: The first column for each dependent variable shows the coefficient estimates in regressions of intraday yield changes or exchange rate returns (FX) on target surprises; the second column adds path surprises as a regressor. Target and path surprises are obtained from intraday data, as explained in the main text. Intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. The sample for the exchange rate is all regular monetary policy announcements from January 2011 to December 2019; for 2- 10- and 30-year yields, from January 2013 to December 2019; and for 5-year yields, from December 2014 to December 2019. Figures expressed in basis points. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Response of the Yield Curve

Table 3.3 shows that, unlike the exchange rate, the yield curve responds to target and path surprises. Information about the future path of the policy rate is expected to have relatively more weight on the middle to long end of the yield curve.[19] Indeed, table 3.3 shows that medium- and long-term yields respond more to path than to target surprises. Moreover, comparing the R^2 statistic of the regressions with one and two factors reveals that path surprises explain 60, 25 and 40% of the variability in 5- 10- and 30-year yields, respectively. The relevance of path surprises for medium- and long-term yields further supports its association with policy statements.

The effects of path surprises on longer-term interest rates improves the implementation of monetary policy. First of all, medium- and long-term yields are more relevant to the spending decisions of households and firms. In addition, since the spillover effects of monetary policy in advanced economies tend to be larger on long-term yields than on short-therm ones (Obstfeld, 2015; Kearns et al., 2018), Banxico can better tame them by communicating information about the future path of its policy rate.

In terms of magnitude, the 2- 5- and 10-year yields in Mexico respond stronger to both surprises than U.S. yields do to the surprises constructed by Gürkaynak et al. (2005). On average, a 25 basis point target tightening surprise in Mexico vs the U.S. rises the yields for those maturities by 17 vs 12, 7 vs 7, 11 vs 3 basis points, respectively; while a 10 basis point path tightening surprise rises them by 5 vs 4, 7 vs 4, 6 vs 3 basis points. According to the expectations hypothesis, this result suggests that long-term inflation expectations in Mexico are less firmly anchored than in the U.S.;[20] even though inflation expectations in Mexico are anchored (De Pooter et al., 2014), it is likely that they are not as well anchored as in the U.S. In addition, the larger reaction in Mexico can also reflect a larger effect of surprises on term premia, which could be explained by the response of yield-oriented investors (Hanson and Stein, 2015); Mexican banks indeed exhibit this

[19] By providing guidance about the future path of the policy rate, statements might be revealing central bank's information about the future course of output and inflation. For instance, a positive path surprise might suggest that the central bank sees greater inflation ahead than previously expected, which would lead to revisions in private forecasts. In relation to this, de Mendonça and de Deus (2019) show that private forecasters in emerging markets update their expectations based on central bank forecasts.

[20] Since prices are flexible in the long run, long-term expected real interest rates would not be affected.

type of reach-for-yield behavior as explained section 3.5.1.

3.4.2 Persistence

Monetary policymakers are not only interested in the initial reaction to the surprises but on how persistent they are. While event studies capture the response to the surprises on the day of a surprise, their persistence over subsequent days is assessed using local projections. Jordà (2005) proposes using local projections instead of vector autoregressions to generate impulse responses that are robust to misspecification.

This exercise is only done for the yield curve because it involves daily frequencies. Daily returns of the currencies of emerging markets do not react to surprises about the policy rate (Kohlscheen, 2014) because daily exchange rate returns are noisy, so the response can only be detected using intraday data (Solís, 2021c). Unreported results confirm that the daily exchange rate returns do not respond to target nor path surprises.

I run the following local projections for the daily changes in the yields:

$$y_{n|m} - y_{t-1} = \alpha_h + \beta_h^1\, Target_t + \beta_h^2\, Path_t + \eta_h^{'} z_{t-1} + u_{n|m}, \tag{3.4}$$

in which h indicates the horizon in days with $h = 0, 1, \ldots, 30$. $Target_t$ and $Path_t$ are equal to the target and path factors on announcement days and zero otherwise. By construction, the factors are uncorrelated, but they are included simultaneously because the estimation is more efficient. z_{t-1} is a vector of lagged variables to control for potential drivers of the yields one day before an announcement. Since the factors are indeed surprises, there is no need to control for other variables. In fact, all the results are essentially the same when no controls are included.[21] However, they are considered here for comparison with the analysis in section 3.5.2 because it involves monthly data for which it is reasonable to include the controls.

The controls included are the exchange rate, the daily return on the MSCI Mexico stock market index, the 10-year U.S. Treasury yield from the Federal Reserve's H.15 dataset to account for global financial conditions, the Cboe's volatility index (VIX) as

[21]The results reported from event studies do not include the controls given the relatively small number of observations but when they are included (unreported), some effects are even stronger.

a measure of risk aversion and economic uncertainty, the J.P. Morgan Emerging Market Bond Index (EMBI) to capture developments in emerging market sovereign bonds, the West Texas Intermediate (WTI) crude oil price given that the budget of the Mexican government is closely tied to it as an oil exporter country, the rate on the 5-year credit default swap (CDS) for Mexico to account for sovereign default risk, and the TED spread as an indicator of credit risk in the global financial sector as well as the local version calculated as the difference between the one-month interbank rate (TIIE28D) and the one-month Mexican Treasury bill rate. These controls are similar to the ones considered by Christensen et al. (2021) who study the liquidity premium in the Mexican bond market.

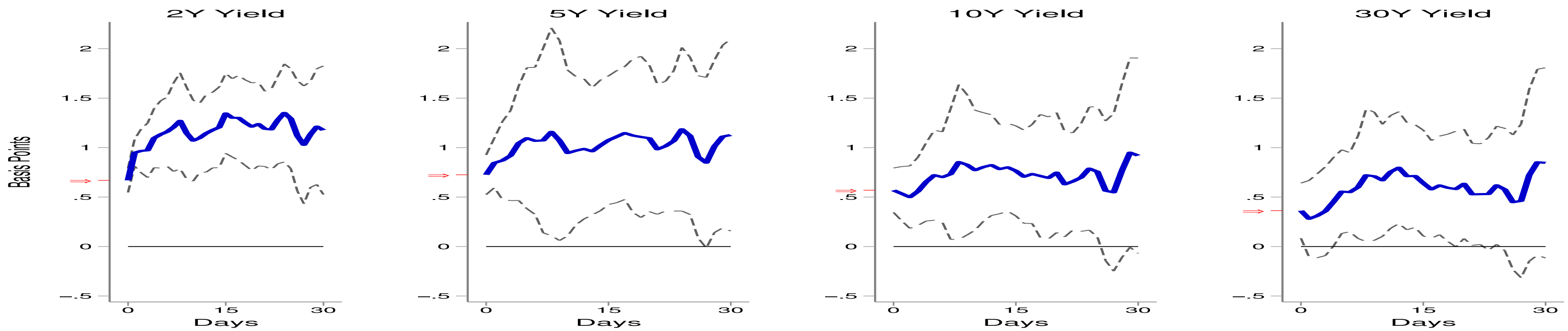
The parameters of interest are β_h^1 and β_h^2. They measure the average response of the yields to the factors at horizon h. The contemporaneous effect (when $h = 0$) on the yields is indicated with an arrow in the figures below. All responses are assessed relative to a one basis point tightening surprise.

Figure 3.3 shows the persistence of bond yields to target and path surprises. First, the effects on the yields last days after an announcement. This post-announcement drift has been identified in advanced economies and has been attributed to slow-moving capital (Brooks et al., 2019). Big players like pension funds and foreign investors might take time to respond to the surprises, as discussed in section 3.5.1. Second, the persistence of the effect decreases with the maturity of the bond. Traditionally, central banks exert relatively more control over the short end of the yield curve with conventional monetary policies. Lastly, the effect of the path factor at all maturities more than doubles a few days after a surprise. Gürkaynak et al. (2005) argue that financial markets may take some time to digest the implications of path surprises. Figure 3.3 supports this view.

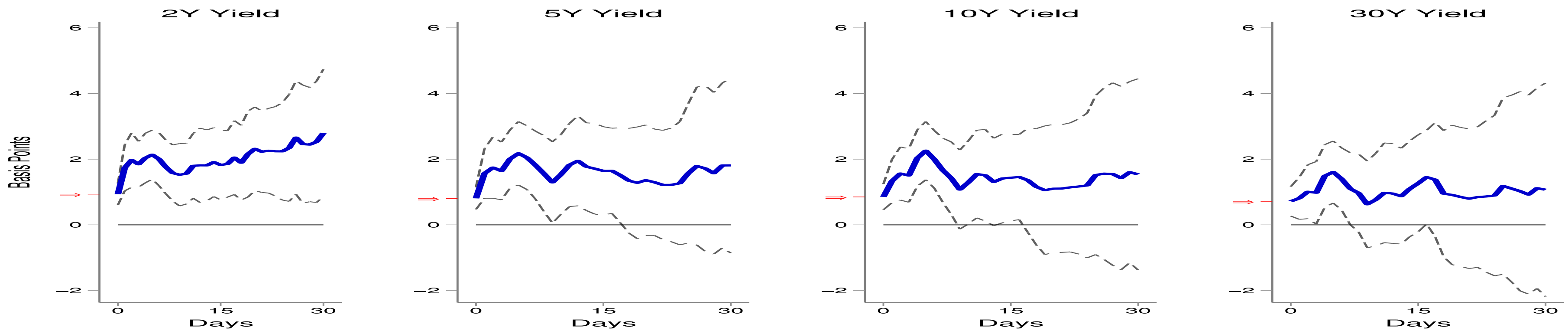
3.5 The Effects of Monetary Policy on Portfolio Flows

The previous section analyzes the responses of asset *prices* to target and path surprises. This section studies how portfolio *flows* respond. While previous studies look at the

Figure 3.3. Response of the Yield Curve to Target and Path Surprises



(a) Target Surprise



(b) Path Surprise

Notes: This figure plots the coefficient estimates and 95% confidence intervals for 1 basis point target and path tightening surprises for yield changes from close of day $t-1$ to day $t+h$, where t is a day with a monetary policy announcement and $h = 0, 1, \ldots, 30$. An arrow indicates the contemporaneous effect (when $h = 0$). The surprises are identified using intraday data around monetary policy announcements, as explained in the main text. The sample includes all regular monetary policy announcements from January 2011 to December 2019. The 95% confidence bands are based on robust standard errors.

(spillover) effects of monetary policy in advanced economies on portfolio flows to emerging markets, this section takes the perspective of the destination country. The evidence shows that both target and path surprises are relevant for portfolio flows.

3.5.1 Daily Flows

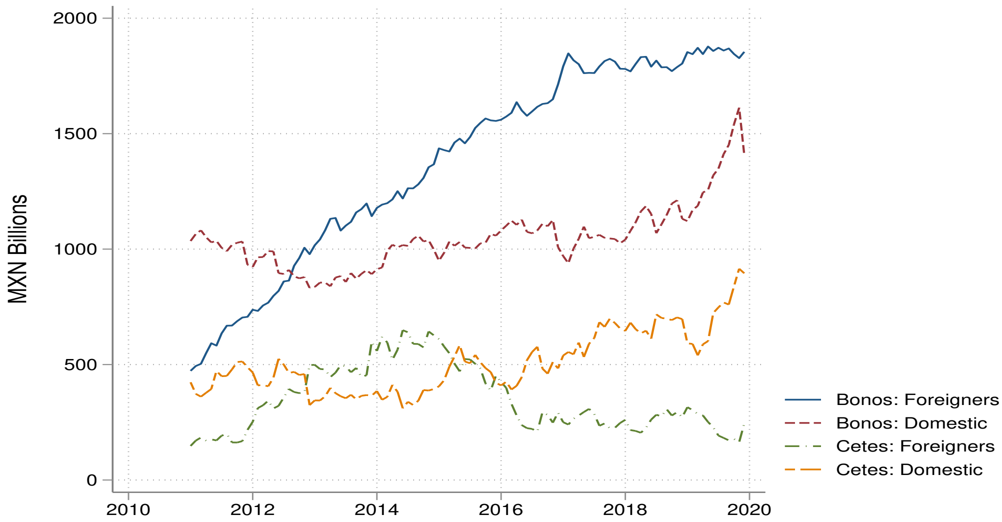
This section exploits the availability of daily data on bonos holdings to analyze how they respond to target and path surprises. Banxico collects daily data on the value of holdings of different types of Mexican government securities: Treasury bills (cetes), fixed-rate bonds (bonos), floating-rate bonds (bondes), inflation-protected bonds (udibonos) and bonds issued by the deposit insurer (bpas). The analysis focuses on the bonos given the prominent role they play in the Mexican bond market (Abreu, 2014),

The data contains the holdings of bonos by domestic and foreign investors. Figure 3.4 compares the level of bonos holdings by residence along with the level of cetes holdings for reference over the period from January 2011 to December 2019. Foreign investors are the main players in the bonos market, their holdings increased substantially since bonos were included in the Citigroup's World Government Bond Index (WGBI) in 2010 (Abreu, 2014). Christensen et al. (2021) document the role of foreign investors in the liquidity of the bonos market. Between late 2012 and early 2015, foreigners were also the main holders of cetes but their share declined since then.

Banxico categorizes domestic investors into banks, mutual funds, pension funds, insurers and other or non-financial investors (firms and households). Figure 3.5 displays the level of bonos holdings by domestic residents over the same period. As can be seen, pension funds are the biggest player in the market. Recently, non-financial investors and banks started accumulating a larger share of bonos. Meanwhile, insurers maintain the smallest and most stable share of bonos among the different types of investors.

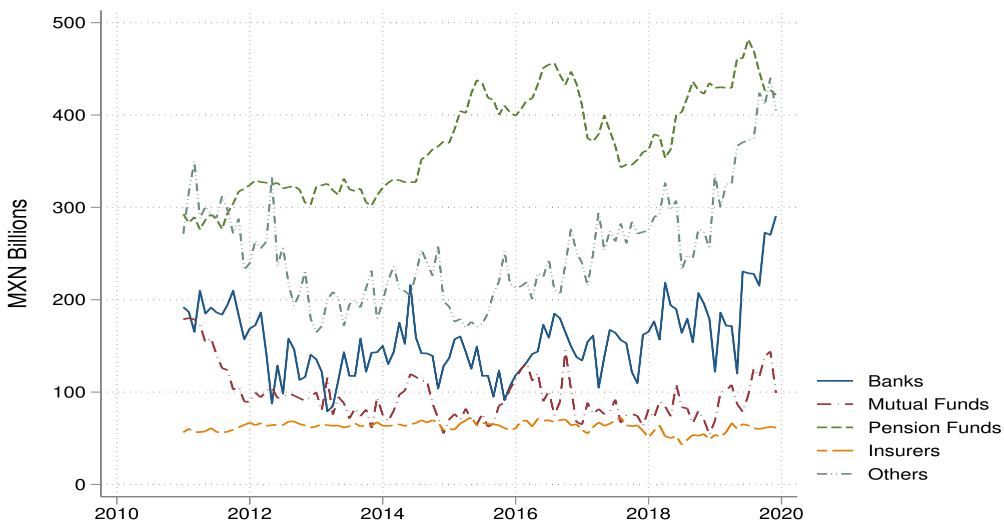
Changes in the nominal value of bonos holdings can reflect either a change in the amount of bonos and/or a change in the value of the bonos. To adjust for valuation effects, I deflate the nominal value of bonos holdings with a rate equal to the percentage change in the price. The daily percentage change in the price of the bonos is approximated

Figure 3.4. Holdings of Cetes and Bonos by Nationality



Notes: This figure shows the net holdings of Mexican Treasury bills (cetes) and fixed-rate sovereign bonds (bonos) by the nationality of the investor from January 2011 to December 2019.

Figure 3.5. Holdings of Bonos by Type of Investor



Notes: This figure shows the net holdings of fixed-rate Mexican sovereign bonds (bonos) by type of investor from January 2011 to December 2019.

as minus the duration times the daily change in the yield. The duration of the bonos is calculated using the par yields from the Bloomberg Fair Value (BFV) curve for Mexico and the average maturity of the bonos reported by Banxico.[22] In this way, a change in the deflated value of bonos holdings only reflects a change in the amount of bonos regardless of price movements. The adjustment makes little difference in the results though.

Contemporaneous Effects

Similar to the case of asset prices, the following event-study regression measures the on-impact effects of target and path surprises on the flows of bonos:

$$\Delta H_t = \beta_0 + \beta_1 Target_t + \beta_2 Path_t + \varepsilon_t, \tag{3.5}$$

in which ΔH_t is the daily change in the (deflated) value of bonos holdings, i.e. the flows into bonos, around monetary policy announcements. The rest is similar to equation (3.3). The model is estimated for each category of investor. Table 3.4 reports the results.

Mutual funds, pensions funds, non-financial investors and foreigners adjust their bonos holdings to at least one of the surprises on the day of a monetary policy announcement; only banks and insurers exhibit no reaction. The responses are economically significant. The most noteworthy ones are those displayed by pension funds to a target surprise and by foreigners to a path surprise. Pension funds buy about MXN 8 billion worth of bonos following a 25 basis point target tightening surprise, while foreigners buy about MXN 10 billion worth of bonos after a 10 basis point path tightening surprise. Therefore, in response to a decline in prices (or a rise in yields) due to a tightening in the monetary stance, as reported in table 3.3, the two most important players in the bonos market increase their holdings.

[22] Every month, Banxico reports the average maturity of government securities outstanding, expressed in days. For the calculation, the average maturity of bonos is expressed in years and rounded to the nearest integer; the same value is used for all the days in a month. The change in the log price of the bond, $\mathrm{d}\log(P)$, is approximately equal to $-D_{mod}\,\mathrm{d}y$, in which D_{mod} is the modified duration. Each day, the BFV yield closest to the average maturity is used to calculate D_{mod} and the change in the yield.

Table 3.4. Response of Daily Bonos Flows to Target and Path Surprises

	Banks	Mutual	Pension	Insurers	Others	Foreign
Target	-0.065	-0.34*	0.32***	0.0088	0.31*	0.32
	(0.18)	(0.19)	(0.086)	(0.030)	(0.17)	(0.21)
Path	-0.29	0.90*	-0.089	0.074	-0.36	1.03***
	(0.53)	(0.48)	(0.24)	(0.061)	(0.56)	(0.35)
No. of Obs.	72	72	72	72	72	72
R^2	0.01	0.09	0.12	0.03	0.03	0.18

Notes: This table shows the coefficient estimates in regressions of different categories of bonos inflows on target and path surprises. Inflows are obtained as the change in the holdings of Mexican bonds. All flows are expressed in billions of Mexican pesos. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period is January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Persistence

As before, I use local projections to analyze the persistence of the effects. Specifically, I run the following regressions:

$$H_{n|m} - H_{t-1} = \alpha_h + \beta_h^1 \, Target_t + \beta_h^2 \, Path_t + \eta_h' z_{t-1} + u_{n|m}, \tag{3.6}$$

in which the dependent variable is the daily changes in the holdings of bonos. The rest is similar to equation (3.4). Figures 3.6 and 3.7 display the impulse responses for bonos flows.

As can be seen, the responses by pension funds to a target surprise and by foreigners to a path surprise are persistent. The delayed adjustment in the bonos holdings of these investors aligns with the post-announcement drift displayed by the yields in figure 3.3 and supports the slow-moving capital explanation discussed in section 3.4.2.

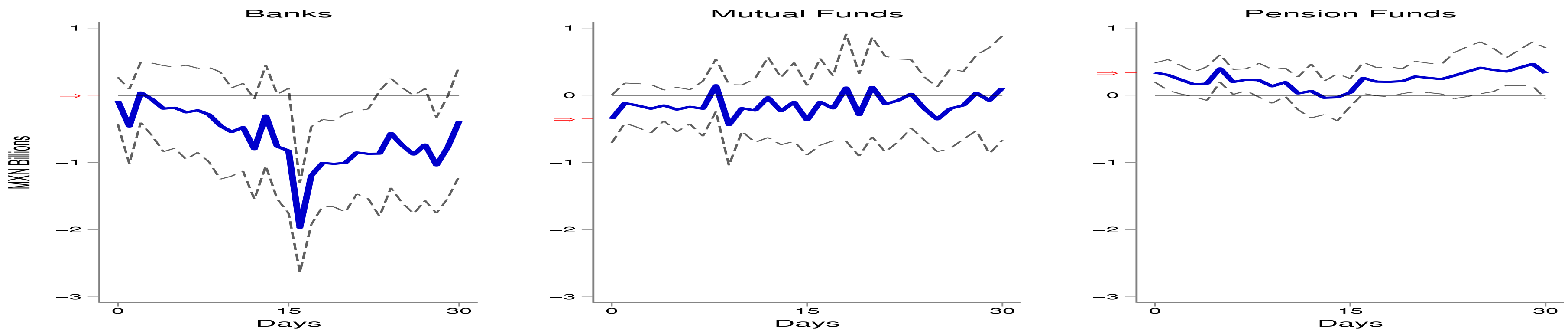
Banks also exhibit a delayed response to target surprises but in the opposite direction to that of pension funds. These two types of investors have different investment profiles. The average maturity of the bonos held by banks is less than 5 years relative to the more than 10 years for pension funds (Abreu, 2014). The top left panel in figure 3.6 indeed suggests that Mexican banks see bonos as riskier assets. The response is consistent with a reach-for-yield behavior by banks, they buy bonos a few days after a target easing surprise. Banks' response supports the mechanism described by Hanson and Stein (2015), in which monetary policy affects term premia due to yield-oriented investors.

3.5.2 Monthly Flows

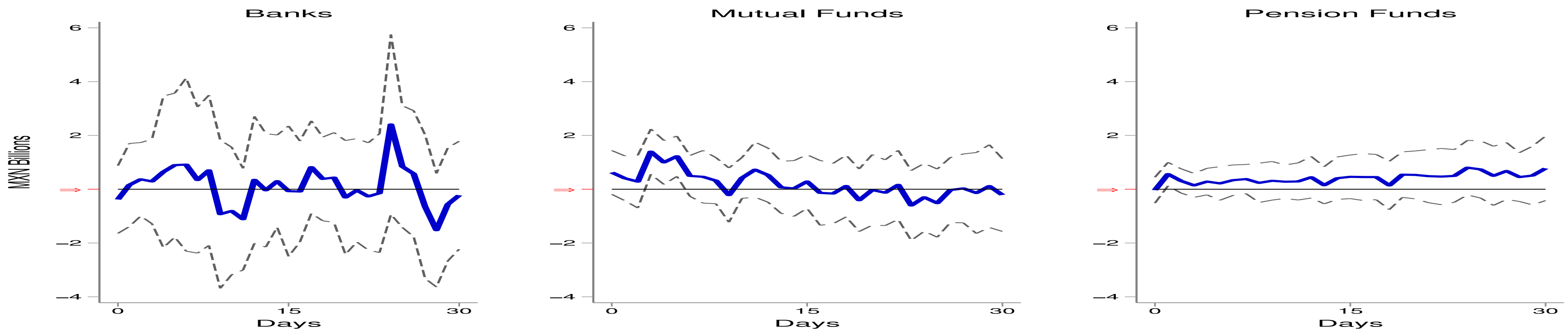
A related research question is whether Banxico's monetary policy also influences cross-border portfolio flows, in addition to the effects it has on the changes of bonos holdings of different investors.

The data on holdings collected by Banxico is unique because of its daily frequency. In fact, one challenge in analyzing the effect of monetary policy surprises on international financial flows is the frequency of the data. Cross-border capital flows can be classified

Figure 3.6. Response of Bonos Flows to Target and Path Surprises



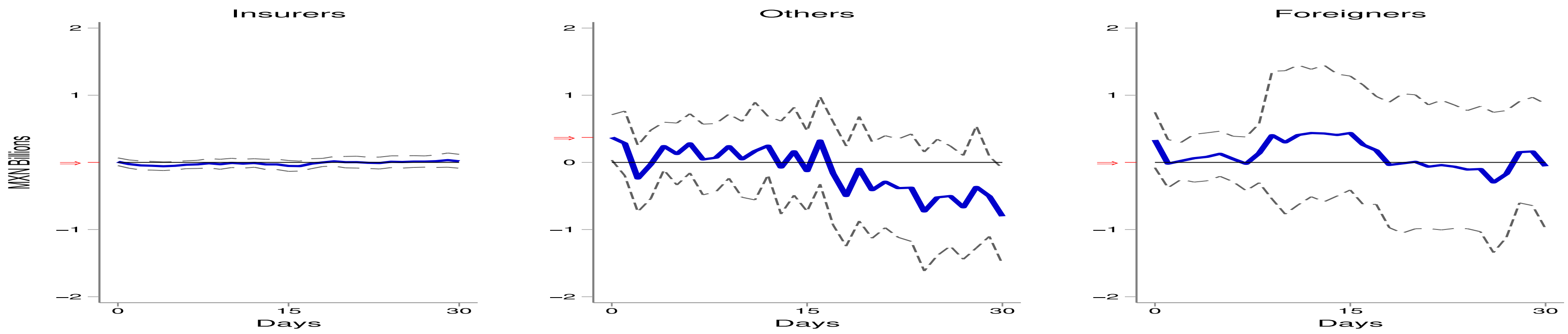
(a) Target Surprise



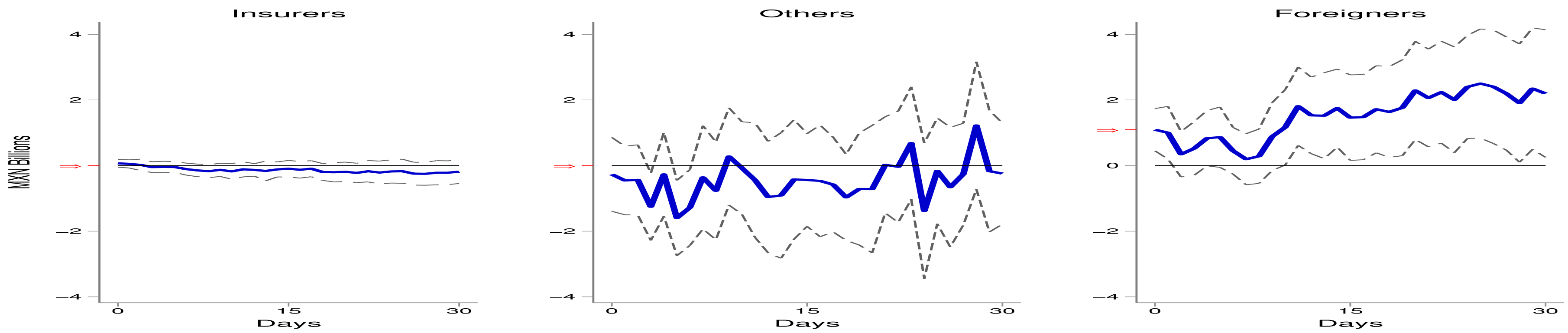
(b) Path Surprise

Notes: This figure plots the coefficient estimates and 95% confidence intervals for 1 basis point target and path tightening surprises for bonos flows from day $t-1$ to day $t+h$, where t is a day with a monetary policy announcement and $h = 0, 1, \ldots, 30$. An arrow indicates the contemporaneous effect (when $h = 0$). The surprises are identified using intraday data around monetary policy announcements, as explained in the main text. The sample includes all regular monetary policy announcements from January 2011 to December 2019. The 95% confidence bands are based on robust standard errors.

Figure 3.7. Response of Bonos Flows to Target and Path Factors (cont.)



(a) Target Surprise



(b) Path Surprise

Notes: This figure plots the coefficient estimates and 95% confidence intervals for 1 basis point target and path tightening surprises for bonos flows from day $t-1$ to day $t+h$, where t is a day with a monetary policy announcement and $h = 0, 1, \ldots, 30$. An arrow indicates the contemporaneous effect (when $h = 0$). The surprises are identified using intraday data around monetary policy announcements, as explained in the main text. The sample includes all regular monetary policy announcements from January 2011 to December 2019. The 95% confidence bands are based on robust standard errors.

broadly as (bond and equity) portfolio flows, foreign direct investment, and banking flows; sometimes international reserves are included as another category. All those flows are reported quarterly, the same frequency of the balance of payments accounts from which they are obtained. However, other sources report portfolio flows more frequently.

Data

The U.S. Treasury International Capital (TIC) system is a monthly database of cross-border securities transactions involving a U.S. counterparty, and is used as an input to calculate the balance of payments accounts for the U.S.[23] TIC data contains disaggregated portfolio flows by country. For many emerging markets, including Mexico, portfolio flows from and to the U.S. are among the most relevant ones. In the case of Mexico, inflows represent sales of securities by Mexican to U.S. investors, and outflows constitute purchases of securities by Mexican from U.S. investors. Inflows and outflows are categorized into six categories each: (1) U.S. Treasury bonds and notes,[24] (2) U.S. government agency bonds,[25] (3) U.S. corporate bonds, (4) U.S. corporate stocks, (5) non-U.S. bonds, (6) non-U.S. stocks. Although it does not hold exactly, non-U.S. bonds and stocks can broadly be considered as local (or Mexican) securities. Finally, net flows are obtained by subtracting outflows to inflows in each of the six categories.

Table 3.5 provides summary statistics for the different categories of TIC flows. The sample starts in January 2011 and ends in December 2019. Transactions involving non-U.S. bonds and Treasury-issued securities stand out as the most significant ones followed by transactions on non-U.S. stocks and U.S. agency bonds.

To compare the effects on cross-border flows, changes in bonos holdings are calculated at the monthly frequency. Table 3.6 summarizes those monthly flows. As mentioned before, foreign investors are the main players in the bonos market; the two most important domestic investors are pension funds and the non-financial sector.

[23]EPFR collects weekly and daily flows data from mutual funds and exchange-traded funds but it is not as comprehensive as the balance of payments data and is not publicly available.

[24]Notes have maturities between 2 and 10 years, while bonds have maturities between 10 and 30 years.

[25]Bonds issued by U.S. government agencies are not guaranteed by the U.S. Treasury.

Table 3.5. Summary Statistics for Portfolios Flows Between Mexico and the U.S.

	Mean	Std. Dev.	Min.	Max.	Obs.
Net Flows: T-Bonds, T-notes	-0.02	2.87	-9.26	6.84	108
Net Flows: U.S. Agency Bonds	0.13	1.09	-2.73	6.15	108
Net Flows: U.S. Corp. Bonds	0.01	0.31	-0.98	2.05	108
Net Flows: U.S. Corp. Stocks	-0.09	0.46	-0.95	1.38	108
Net Flows: Non-U.S. Bonds	0.88	2.08	-4.67	9.50	108
Net Flows: Non-U.S. Stocks	-0.07	0.30	-0.71	0.73	108
Inflows: T-Bonds, T-notes	3.80	3.13	0.19	17.23	108
Inflows: U.S. Agency Bonds	1.63	1.07	0.08	7.97	108
Inflows: U.S. Corp. Bonds	0.28	0.30	0.07	2.24	108
Inflows: U.S. Corp. Stocks	2.76	0.63	1.30	4.49	108
Inflows: Non-U.S. Bonds	5.28	2.34	1.52	14.17	108
Inflows: Non-U.S. Stocks	2.62	0.74	1.43	5.12	108
Outflows: T-Bonds, T-notes	3.82	2.89	0.10	18.29	108
Outflows: U.S. Agency Bonds	1.50	0.63	0.36	3.76	108
Outflows: U.S. Corp. Bonds	0.27	0.21	0.07	1.37	108
Outflows: U.S. Corp. Stocks	2.84	0.60	1.72	4.98	108
Outflows: Non-U.S. Bonds	4.40	2.09	1.12	10.70	108
Outflows: Non-U.S. Stocks	2.69	0.74	1.47	4.95	108

Notes: Amounts expressed in billions of U.S. dollars. The sample period goes from January 2011 to December 2019. Net flows are inflows minus outflows. Inflows are sales of securities by Mexican to U.S. investors. Outflows are purchases of securities by Mexican from U.S. investors.

Effects on Monthly Portfolio Flows

For each flow category, the following model is used to analyze the effects of target and path surprises on portfolio flows at the monthly frequency:

$$w_t = \beta_0 + \beta_1 Target_t + \beta_2 Path_t + \sum_{j=1}^{p} \gamma_j w_{t-j} + \eta^{'} z_{t-1} + \nu_t, \tag{3.7}$$

in which w_t denotes the respective portfolio flow, and the lags w_{t-j} up to order p capture the persistence in flow data; the lag order for each flow category is selected using the Bayesian information criterion. $Target_t$ and $Path_t$ are equal to the target and path surprises identified with intraday data if there is a monetary policy announcement in the respective month and zero otherwise.[26] The control variables are the same as for equation

[26] In the few cases in which there is more than one announcement during a month, the monthly surprises are equal to the sum of the values in the month.

Table 3.6. Summary Statistics for Cetes and Bonos Flows

	Mean	Std. Dev.	Min.	Max.	Obs.
Cetes: Banks	0.47	18.42	-47.19	41.15	108
Cetes: Mutual Funds	0.24	19.02	-50.42	58.72	108
Cetes: Pension Funds	1.85	10.53	-28.03	53.81	108
Cetes: Insurers	0.30	3.52	-7.70	9.29	108
Cetes: Others	0.81	24.04	-59.52	57.62	108
Cetes: Foreigners	1.34	37.64	-75.63	145.17	108
Bonos: Banks	0.31	29.79	-65.72	108.77	108
Bonos: Mutual Funds	-0.25	17.78	-44.88	55.60	108
Bonos: Pension Funds	1.19	12.06	-32.72	37.27	108
Bonos: Insurers	0.04	3.97	-11.45	9.75	108
Bonos: Others	1.54	29.11	-96.72	79.79	108
Bonos: Foreigners	12.89	28.46	-69.32	76.12	108

Notes: This table shows summary statistics for the monthly flows of cetes and bonos by different groups of investors. The flows are equal to the change in the value of holdings of government securities. The value is net of valuation effects, as explained in the main text. Foreigners refer to holdings by non-Mexican investors. Amounts expressed in billions of Mexican pesos. The sample period goes from January 2011 to December 2019.

(3.3), with their value taken at the last day of the month and the return on the MSCI Mexico stock market index computed monthly.

Tables 3.7 and 3.8 respectively show that portfolio inflows and outflows between Mexico and the U.S. do respond to target and path surprises. Nevertheless, the effects on net flows are not significant (see Table 3.A.4 in the appendix).

The most significant effects of a target surprise are seen on non-U.S. stocks. A target easing surprise increases inflows into non-U.S. stocks, which likely reflects more willingness of U.S. investors to hold risky local assets. Relatedly, but from a home-country perspective, Chen et al. (2014) find that easing surprises in the U.S. are associated with higher portfolio equity flows into emerging markets. Tables 3.7 therefore suggests that the central bank in the destination country can trigger a reach-for-yield behavior in U.S. investors. Tables 3.8 shows that domestic investors also increase their purchases of non-U.S. stocks owned by U.S. investors but in smaller magnitude, so net inflows into non-U.S. stocks increase following a target easing surprise; the effect on net inflows, however, is not significant (see Table 3.A.4 in the appendix).

Table 3.7. Response of Portfolio Inflows to Target and Path Surprises

	T-Notes/Bonds	Agency Bonds	U.S. Corp. Bonds	U.S. Corp. Stocks	Non-U.S. Bonds	Non-U.S. Stocks
Target	-0.062	0.0055	-0.0036	-0.0014	-0.042	-0.019***
	(0.054)	(0.017)	(0.0042)	(0.0058)	(0.038)	(0.0040)
Path	0.13	0.073**	0.012	-0.015	0.091	0.0092
	(0.17)	(0.036)	(0.010)	(0.020)	(0.10)	(0.014)
Lags	0	1	3	2	1	3
Obs.	108	108	108	108	108	108
R^2	0.15	0.27	0.36	0.30	0.26	0.67

Notes: This table shows the coefficient estimates in regressions of different categories of portfolio inflows on target and path surprises. Inflows are sales of securities by Mexican to U.S. investors. All flows are expressed in billions of U.S. dollars. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period goes from January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 3.8. Response of Portfolio Outflows to Target and Path Surprises

	T-Notes/Bonds	Agency Bonds	U.S. Corp. Bonds	U.S. Corp. Stocks	Non-U.S. Bonds	Non-U.S. Stocks
Target	-0.017	0.0079	0.0035*	-0.0048	-0.024	-0.013***
	(0.032)	(0.0085)	(0.0021)	(0.0093)	(0.030)	(0.0047)
Path	0.20	0.020	0.0021	-0.0080	0.0031	0.010
	(0.13)	(0.018)	(0.0056)	(0.016)	(0.055)	(0.016)
Lags	0	3	2	2	3	3
Obs.	108	108	108	108	108	108
R^2	0.13	0.33	0.54	0.26	0.38	0.69

Notes: This table shows the coefficient estimates in regressions of different categories of portfolio outflows on target and path surprises. Outflows are purchases of securities by Mexican from U.S. investors. All flows are expressed in billions of U.S. dollars. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period goes from January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Tables 3.8 indicates that inflows into U.S. agency bonds respond to path surprises. They decline following a path easing surprise. This is better understood from the perspective of Mexican investors. According to the results in section 3.4, a path easing surprise reduces sovereign bond yields in Mexico so, ceteris paribus, the spread between bonos and the yield of U.S. agency bonds changes making the latter more attractive. Mexican investors rebalance their portfolios by lowering their sales of agency bonds to U.S. investors. This result suggests that local investors use non-Mexican securities to rebalance their portfolios in response to Banxico's monetary policy decisions.

In contrast to the results involving daily flows of bonos by foreign investors, the bilateral flows on non-U.S. bonds do not respond to Banxico's monetary policy. Two potential reasons can explain this result. First, non-U.S. bonds could include corporate Mexican bonds or even non-Mexican bonds. These other types of bonds might be less sensible to target and path surprises. Nevertheless, even if that category exclusively comprises bonds issued by the Mexican government, it mixes together at least cetes and bonos. Tables 3.A.2 and 3.A.3 in the appendix show that cetes flows by foreign investors do not respond to target nor path surprises. Second, the results in section 3.5.1 refer to non-Mexican investors, while the TIC data captures transactions involving a U.S. counterparty. The evidence thus suggests that foreign non-U.S. investors are important players in the bonos market.

Table 3.9 reports the effects of target and path surprises on the monthly bonos flows. Unlike the results with daily flows reported in table 3.4, significant effects are harder to detect with monthly data. Even so, the effects on the bonos flows by foreigners to a target surprise remain. This makes the results using TIC data more promising since, with access to better data, there might be more significant effects than the ones reported in tables 3.7 and 3.8. Data on cross-border portfolio flows at higher frequencies (e.g. weekly, daily), categorized by type of instrument and/or disaggregated by maturity could help to better characterize the effects of Banxico's monetary policy on cross-border capital flows.

Summing up, portfolio flows, even cross-border ones, react to target and path surprises. This means that capital flows to emerging markets respond not only to the

Table 3.9. Response of Monthly Bonos Flows to Target and Path Surprises

	Banks	Mutual	Pension	Insurers	Others	Foreign
Target	-0.86*	-0.34	0.053	0.00021	-0.43	0.36
	(0.47)	(0.25)	(0.15)	(0.039)	(0.34)	(0.52)
Path	-0.89	0.19	0.22	-0.17	0.38	1.90**
	(0.92)	(0.70)	(0.46)	(0.12)	(0.81)	(0.93)
Lags	3	1	0	2	1	0
Obs.	108	108	108	108	108	108
R^2	0.33	0.17	0.12	0.15	0.23	0.12

Notes: This table shows the coefficient estimates in regressions of different categories of Mexican bond inflows on target and path surprises. Inflows are obtained as the change in the holdings of Mexican bonds. All flows are expressed in billions of Mexican pesos. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period goes from January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

monetary policy of advanced economies (Chen et al., 2014; Curcuru et al., 2015; Fischer, 2020) but to that of the destination country.

3.6 Concluding Remarks

This paper uses a new dataset to identify monetary policy surprises in an emerging economy. The evidence indicates that surprises in the policy rate and about its future path are relevant for both asset prices and portfolio flows. The multidimensionality of monetary policy is therefore not restricted to advanced economies. By having the ability to alter market expectations about the future path of the policy rate via statements, central banks in emerging markets can influence medium and long-term interest rates, which are the ones that ultimately transmit to the broader economy. Furthermore, they have room to deal with the spillover effects from the policies implemented by central banks in advanced economies as well as to conduct monetary policy in case their policy rate were to be constrained by the zero lower bound.

Given the importance of statements documented here, emerging markets should consider best practices in monetary policy communications, including brief, clear and concise language without compromising the main message. References to non-monetary policy issues (e.g. structural reforms) in statements should be assessed on a case-by-case basis. On this regard, Banxico committed to issue clear and concise statements and made its guidelines publicly available in February 2020.[27]

The results in this paper can be extended in several directions. For instance, to further understand how bond yields respond to monetary policy, one can analyze how target and path surprises transmit to the expected future short rate and the term premium in bond yields; the decomposition proposed by Solís (2021b) for the yields of emerging markets is relevant to address this issue. In addition, the destination-country perspective can be relevant for emerging markets in connection with macroprudential policies. One could study, for instance, the interaction of target and path surprises with different macropru-

[27] The press release is available at https://www.banxico.org.mx/publicaciones-y-prensa/miscelaneos/%7B4C09D772-2CDF-8BD6-3F04-65DE03CA6212%7D.pdf.

dential policies, including capital controls given the response of portfolio flows to target and path surprises documented here. Finally, more research is needed to assess the extent to which the results reported here apply to other emerging markets.

Appendix 3.A Supplementary Tables

Table 3.A.1. The Response of Swap Rates to the Target and Path Factors

	3M-Swap				1Y-Swap			
	Intraday		Daily		Intraday		Daily	
Intraday Target Factor	0.999***	0.999***			0.983***	0.983***		
	(0.008)	(0.008)			(0.046)	(0.013)		
Intraday Path Factor		0.000				1.050***		
		(0.022)				(0.038)		
Daily Target Factor			1.001***	1.001***			0.942***	0.942***
			(0.007)	(0.007)			(0.065)	(0.011)
Daily Path Factor				0.000				0.816***
				(0.011)				(0.019)
Constant	-0.480***	-0.480***	-0.083	-0.083	-0.286	-0.286***	0.062	0.062
	(0.061)	(0.062)	(0.061)	(0.061)	(0.435)	(0.104)	(0.501)	(0.115)
Observations	72	72	155	155	72	72	155	155
R-squared	0.996	0.996	0.994	0.994	0.819	0.990	0.691	0.984

Notes: For the 3-month swap rate, the table shows the coefficient estimates in regressions of intraday and daily changes in the 3-month swap rate on the target and path factors obtained from intraday and daily data, as explained in the main text. Similarly for the 1-year swap rate. Daily changes are calculated around monetary policy announcements; intraday changes are calculated starting 10 minutes before to 20 minutes after a monetary policy announcement. The sample is all regular monetary policy announcements until December 2019, with intraday data the sample starts in January 2011 and with daily data it starts in January 2004. All variables are expressed in basis points. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 3.A.2. Response of Daily Cetes Flows to Target and Path Surprises

	Banks	Mutual	Pension	Insurers	Others	Foreign
Target	0.019	-0.067	-0.027	-0.0066	0.069	-0.090
	(0.12)	(0.11)	(0.051)	(0.0083)	(0.15)	(0.12)
Path	0.087	-0.35	0.091	0.029	0.19	0.10
	(0.38)	(0.23)	(0.20)	(0.044)	(0.55)	(0.35)
No. of Obs.	72	72	72	72	72	72
R^2	0.00	0.04	0.01	0.01	0.01	0.01

Notes: This table shows the coefficient estimates in regressions of different categories of Cetes inflows on target and path surprises. The inflows are obtained as the change in the holdings of cetes. All flows are expressed in billions of Mexican pesos. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period is January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 3.A.3. Response of Monthly Cetes Flows to Target and Path Surprises

	Banks	Mutual	Pension	Insurers	Others	Foreign
Target	0.21	-0.14	0.076	0.026	0.25	-0.37
	(0.22)	(0.23)	(0.11)	(0.032)	(0.32)	(0.65)
Path	-0.011	-0.61	-0.90***	-0.031	0.68	-0.97
	(0.52)	(0.51)	(0.30)	(0.14)	(0.69)	(1.00)
Lags	1	0	0	0	1	0
Obs.	108	108	108	108	108	108
R^2	0.29	0.12	0.19	0.09	0.13	0.22

Notes: This table shows the coefficient estimates in regressions of different categories of Cetes inflows on target and path surprises. The inflows are obtained as the change in the holdings of cetes. All flows are expressed in billions of Mexican pesos. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period goes from January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

Table 3.A.4. Response of Portfolio Net Flows to Target and Path Surprises

	T-Notes/Bonds	Agency Bonds	U.S. Corp. Bonds	U.S. Corp. Stocks	Non-U.S. Bonds	Non-U.S. Stocks
Target	-0.051	-0.0031	-0.0076	0.0043	-0.014	-0.0055
	(0.037)	(0.017)	(0.0053)	(0.0065)	(0.024)	(0.0033)
Path	-0.073	0.063	0.011	-0.0072	0.10	0.0017
	(0.11)	(0.045)	(0.011)	(0.016)	(0.10)	(0.0080)
Lags	1	1	0	0	0	2
Obs.	108	108	108	108	108	108
R^2	0.25	0.18	0.13	0.16	0.14	0.29

Notes: This table shows the coefficient estimates in regressions of different categories of portfolio net flows on target and path surprises. Net flows are inflows minus outflows. Inflows are sales of securities by Mexican to U.S. investors. Outflows are purchases of securities by Mexican from U.S. investors. All flows are expressed in billions of U.S. dollars. The surprises are equal to the estimated value (as explained in the main text) if there was a monetary policy announcement in the respective month and zero otherwise. The lag order for each flow category is selected using the Bayesian information criterion. The sample period goes from January 2011 to December 2019. All regressions include a constant. Robust standard errors are shown in parentheses. *, **, *** asterisks respectively indicate significance at the 10%, 5% and 1% level.

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